SECTION 308
TASK XIV
SEPTIC SYSTEMS

FIELD EVALUATION OF FOUR ONSITE DISPOSAL SYSTEMS AND THEIR IMPACTS TO SHALLOW GROUNDWATER IN THE COASTAL ZONE OF SOUTH CAROLINA

Prepared By:
Lisa M. Hajjar

Office of Ocean and Coastal Resource Management
South Carolina Department of Health and Environmental Control
1362 McMillan Avenue, Suite 400
Charleston, South Carolina 29405

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INTRODUCTION

South Carolina's coastal zone is rich in both its variety and abundance of natural resources. Although the state's coastline is only 187 miles long, its numerous estuaries, bays, rivers and creeks combine to create an actual shoreline nearly 3,000 miles in length. Alongside the maze of estuaries and creeks flourish thousands of acres of marsh, constituting some of the richest, most productive areas on earth - areas vital to the existence of the majority of marine life found in both offshore and inshore waters of our coast. Estuaries play a vital role as breeding and/or nursery grounds for commercially important species such as shrimp, crabs, oysters, clams and numerous kinds of fish (S.C. Coastal Council, 1993).

The estuarine ecosystem is delicately balanced and extremely vulnerable to the external stresses imposed on it by man. The decline in oyster production is one example of this. Since the turn of the century, South Carolina oyster production has decreased by more than 90% while nationwide production has decreased by 76% (Scott, 1996). Although there are many contributing factors, high fecal coliform bacteria levels are often cited as a reason for closing oyster beds to harvesting. The potential sources of fecal coliform bacteria include septic systems, sewer system overflows, pet waste, wildlife fecal waste and fecal waste from mismanaged livestock operations. These sources can also contribute excessive nutrient loads which can result in eutrophication of surface waters.

In developed coastal areas, septic systems are often blamed for polluting surface waters with fecal coliform bacteria. This blame may be justified for older, unmaintained systems, as many were permitted under the pre-1986 septic system regulations. These earlier regulations relied on less proven methods of site evaluation (e.g., the 'perc' test) and included fewer options for system design modifications. In addition, older systems that have not been properly maintained are more likely to fail. Even properly functioning systems can leach excessive nitrates into groundwater.

Today, many areas of our coastal zone are being developed at a rapid pace and septic systems are still relied upon for providing wastewater treatment. Although the State's onsite program utilizes more reliable site evaluation techniques (e.g., soil redoxymorphic features) to determine seasonal high water table, and the current regulations allow for flexibility in system design, blame is still being placed on septic systems for polluting surface waters.

Septic systems that are failing on the surface of the ground are fairly easy to detect using obvious signs such as effluent on the ground, slowly draining pipes or sewage backing up into the house, and lush green grass growing over the trench lines. Septic systems that are failing below the surface of the ground are much more difficult to detect without the use of groundwater monitoring or dye tracer studies. These subsurface failures may be impacting groundwater and surface waters that are closely hydrologically connected.

The nature of our coast is such that the potential is great for polluted groundwater to impact shellfish grounds and other sensitive coastal resources that are closely hydrologically connected. In addition, South Carolina has been accused of having some of the weakest onsite regulations in the region, particularly with regard to separation distance between the trench bottom and the seasonal high water table (SHWT). Whereas S.C. requires a minimum of six inches of separation, the majority of coastal states require a minimum separation distance of two feet and some states require as much as four to five feet of separation. There is a large body of research from other states that supports the greater separation distances (Anderson *et al.*, 1993; Cogger *et al.,* 1988; Duncan *et al.*, 1994).

South Carolina's standards for individual waste disposal systems (R.61-56) became effective in June 1986. Several DHEC or DHEC-sponsored studies on coastal zone septic systems have been conducted prior to and subsequent to the adoption of R.61-56. A DHEC study on the hydrogeology of the shallow aquifers of the lower Coastal Plain of South Carolina and the impacts of land disposal sites on the shallow groundwater found that "the highest degree of groundwater contamination was found near tile field systems that were located in very permeable sediments with a shallow water table." In addition, it stated that "the greatest volume of contaminants entering the groundwater is from tile field effluent contributed by subdivisions and trailer parks" (SCDHEC, 1980).

A collaborative research project between DHEC and the University of South Carolina was initiated in the late 1980's on numerous older, newer, and experimental systems all across the coastal zone. Due to reduced funding this project was not completed, and due to extremely dry weather it was not successful in evaluating the six-inch separation distance to SHWT. However, the project completion report identified several areas needing further study including: a) the effects of soil type and layering on groundwater mounding under septic systems; b) the separation distance (to SHWT) for all soil classes; and c) the residential absorption field standards to determine if drain fields are adequately sized (Meadows *et al.,* 1991).

An epidemiological and microbiological study related to the Meadows study was conducted by a USC doctoral student. This study concluded that coastal South Carolina residents who consume groundwater from shallow aquifers that are associated with a septic system (especially from wells which are less than 50 feet from a septic system), and who swim in estuarine water and consume estuarine shellfish in areas drained by septic tanks, are at increased risk of contracting bacterial enteritis. This study also noted the presence of bacterial serotypes in oysters that were similar to the ones present in drainfield wells, indicating the effect of contamination from drainfield runoff (El-Figi, 1990).

The objective of this study was to determine if septic systems installed under the current regulations (R. 61-56) performed adequately to protect shallow groundwater and closely hydrologically connected surface waters.

Background On Monitoring Parameters

Chloride

Chlorides are naturally occurring in both surface and ground waters and are also found in household and community wastewaters. Septic systems are ineffective at removing chloride from effluent. Chloride is, therefore, a useful tracer or indicator of septic tank effluent. It is considered a conservative indicator because it is a soluble anion and does not undergo biological or biochemical transformations in the septic tank, the soil or the groundwater. By comparing the chloride levels in an upgradient well with levels in downgradient wells, one can determine if the downgradient wells are detecting the effluent plume and then assess the transformations of other elements that may have occurred.

Nitrogen

Unlike chloride, the nitrogen in a septic tank system can undergo many changes. These changes are complex and for the sake of brevity will only be described in basic terms here. Total nitrogen levels in septic tank effluent range from 40-80 mg/l and occur primarily in the ammonium (about 75%) and organic (about 25%) forms. Anaerobic conditions in the septic tank are responsible for the conversion of organic nitrogen to ammonium and for the very low levels of nitrate in the tank. Septic tanks are ineffective at removing nitrogen from effluent.

Ammonium is the predominant form of nitrogen that enters the soil from the trenches. Ammonium can be adsorbed by the soil and if aerobic conditions are present it is converted to nitrate. As a soluble anion, nitrate is highly mobile and moves readily with groundwater, particularly within highly permeable subsurface materials. Under anaerobic conditions, both in the soil and in the groundwater, denitrification (transformation of nitrate to nitrogen gas) can occur which reduces the total nitrogen load to the subsurface environment.

Total Phosphorus

Total phosphorus levels in septic tank effluent typically range from 11-31 mg/l. The septic tank alone is not effective at reducing phosphorus levels, but the soil adsorption system is. Phosphorus undergoes many transformations in the soil environment which are highly dependent on soil characteristics. Movement of phosphorus from drainfields is usually insignificant and where it occurs, levels generally decrease rapidly with distance from the system.

Fecal Coliform Bacteria

The presence and amount of fecal coliform bacteria in shellfish harvesting waters has long been used as an indicator organism of less numerous and less easily detectable pathogenic organisms. Although fecal coliforms are found in the intestines of all warm-blooded animals, septic systems are often blamed as the source of the bacteria in surface waters. In the absence of direct surface breakthrough and runoff from failing septic systems, subsurface movement of coliforms through the soil absorption system and the groundwater is a suspected pathway for contamination.

Attenuation of bacteria and viruses by the soil adsorption system is through physical and biological means and is affected by soil properties, water table conditions, and even system design and maintenance. Simply stated, intestinal bacteria survive best under anaerobic conditions and rapidly die off under aerobic conditions. Bacteria can be short-circuited to the groundwater when the water table is in or near the drainfield trenches. Whereas the lateral movement of bacteria in groundwater can be highly variable, the presence of an adequate vadose (unsaturated) zone beneath the drainfield is important to reducing the threat of bacterial transport.

MATERIALS AND METHODS

Site Selection

Four residences in Charleston County were chosen for this study based on their proximity to surface water, the age of the onsite system, and on the homeowner's willingness to participate in the study. The sites are located on James Island (JI), Yonges Island (YI), Isle of Palms (IP), and Ravenel (RA). The locations of Charleston County and each site within the county are shown in Figures 1-5. Each site has an onsite system that was installed in accordance with the current onsite regulations (R. 61-56, effective 1986). Scaled site maps that show each system layout and system description are included with the data figures and discussion for each site. Copies of the onsite permits are included as Appendix A. Toward the end of the project, the homeowners completed a septic system performance survey regarding their experiences and/or problems with their onsite system.

Monitoring Well Installation

Each site had six shallow groundwater monitoring wells installed in November, 1995. A DHEC hydrogeologist who is a certified well driller assisted with well placement and installation. One upgradient, one in-field (i.e., between two trenches in the drainfield) and four downgradient wells were installed per site. The purpose of an upgradient well was to establish the background water quality conditions, i.e., outside of the influence of the drainfield. An in-field well was used to measure the quality of the groundwater as affected by effluent treated solely by the vadose zone (unsaturated zone) immediately beneath the drainfield. The purpose of the downgradient wells was to measure the movement of the septic tank effluent plume and the transformations of certain effluent constituents with distance from the drainfield. Wells 3, 4, and 5 at each site were located 10, 15, and 25 feet, respectively, downgradient from the edge of the drainfield. Distances from the onsite system to well 6 varied from site to site, with well 6 typically being the well closest to the surface water.

The wells were constructed of 2-inch, threaded, schedule 40 PVC pipe, 0.01-inch slotted PVC screen and PVC well points. The wells were installed using 3 1/4-inch hand soil augers. Since it is very difficult to auger much below the surface of the water table using hand soil augers, each well was installed only to the depth of the water table at time of installation. With a well point on the bottom of each well, a few additional inches were gained by pounding the well in further immediately after placing it in the ground. The wells were backfilled with filter-pack sand and bentonite pellets. Since the wells were of a temporary nature, no cement was used. The wells were terminated just below the ground surface and protected with turf-style valve boxes and locking caps (see Fig. 6 for a typical well construction diagram).

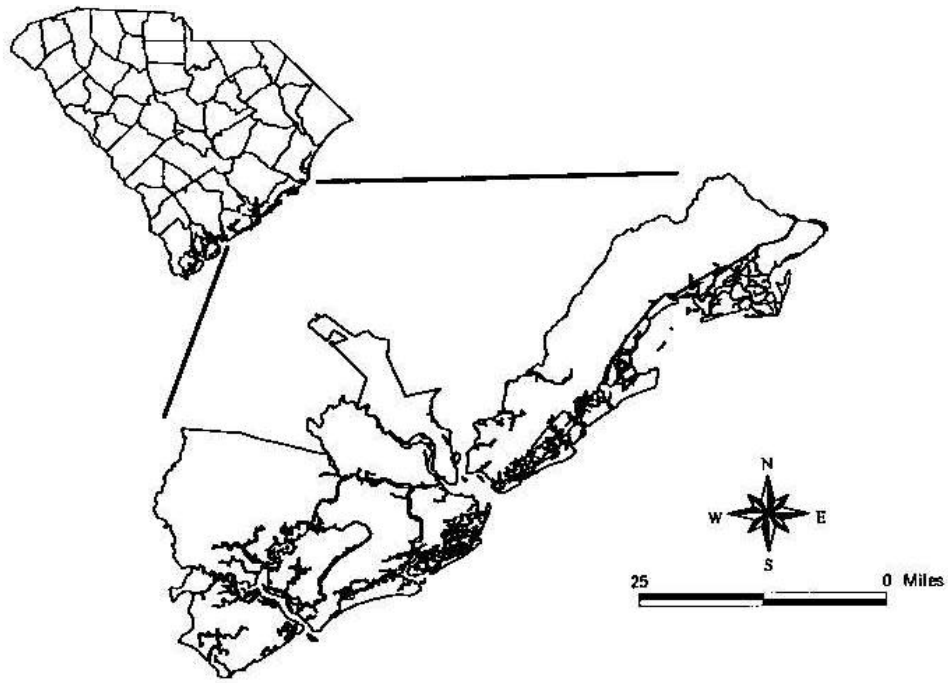


Figure 1 Map of Charleston County.

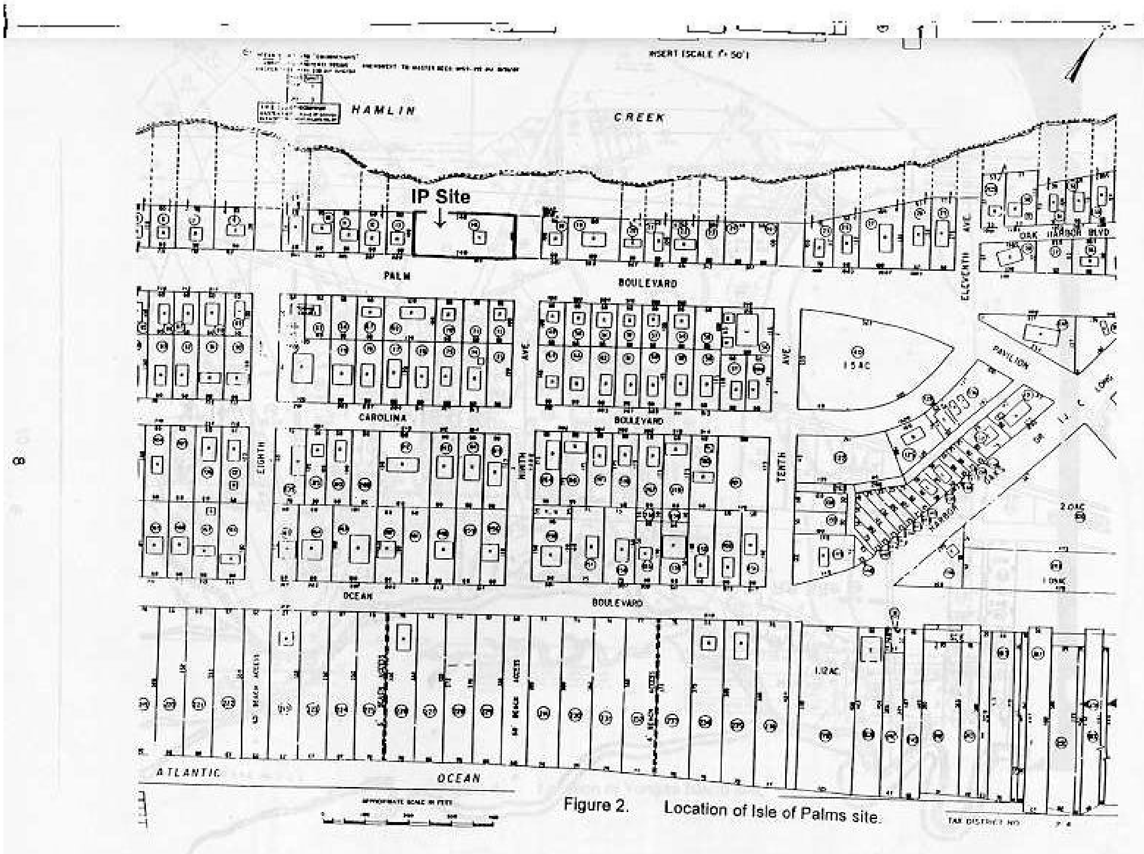


Figure 2. Location of Isle of Palms site.

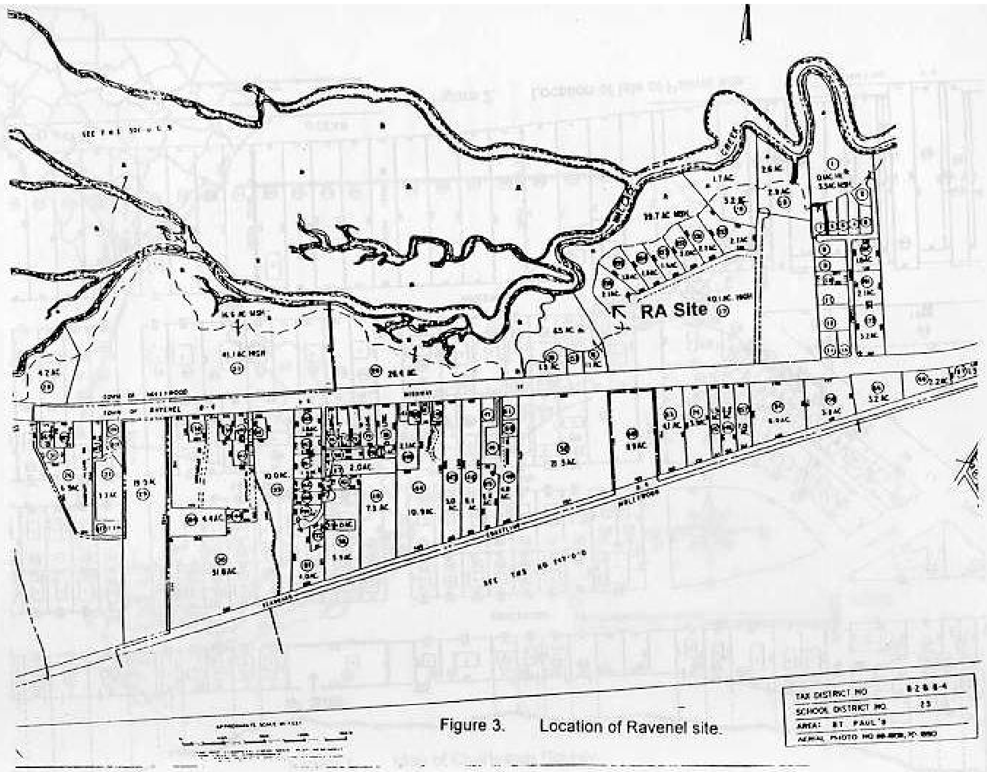


Figure 3. Location of Ravenel site.

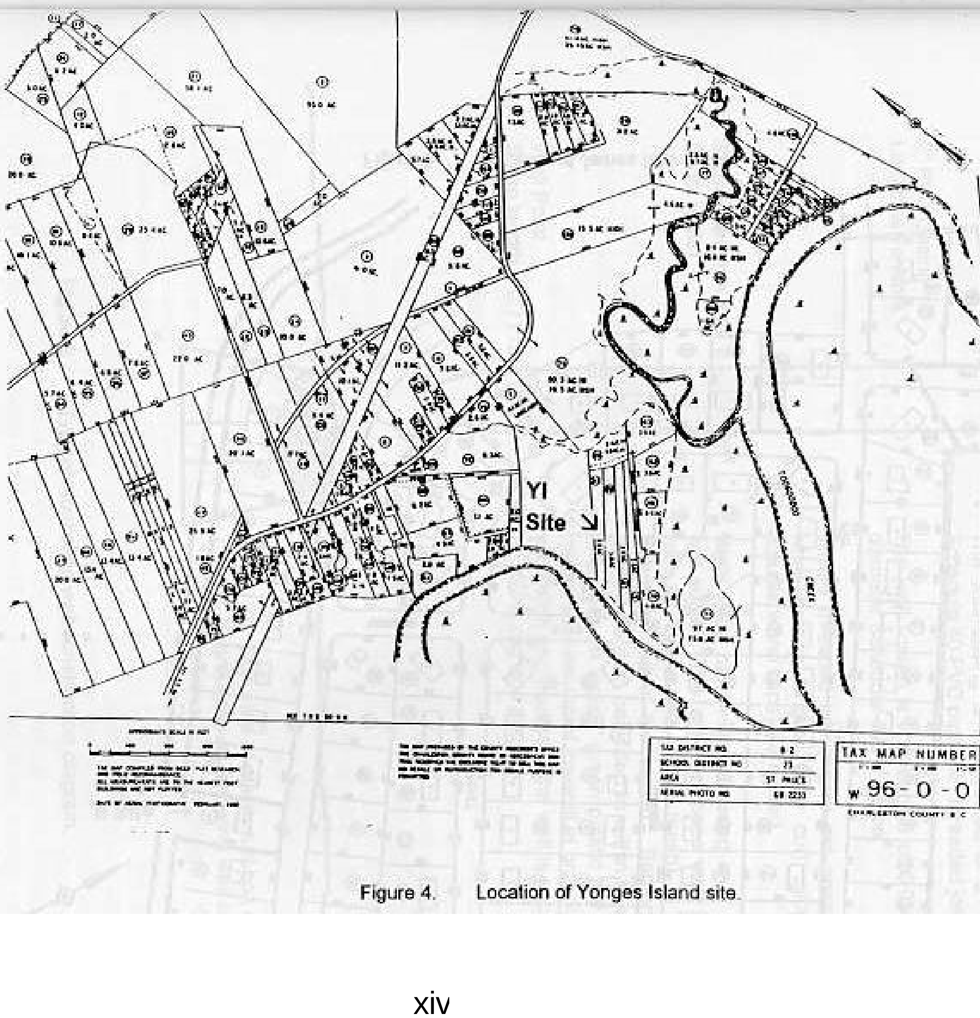


Figure 4. Location of Yonges Island site.

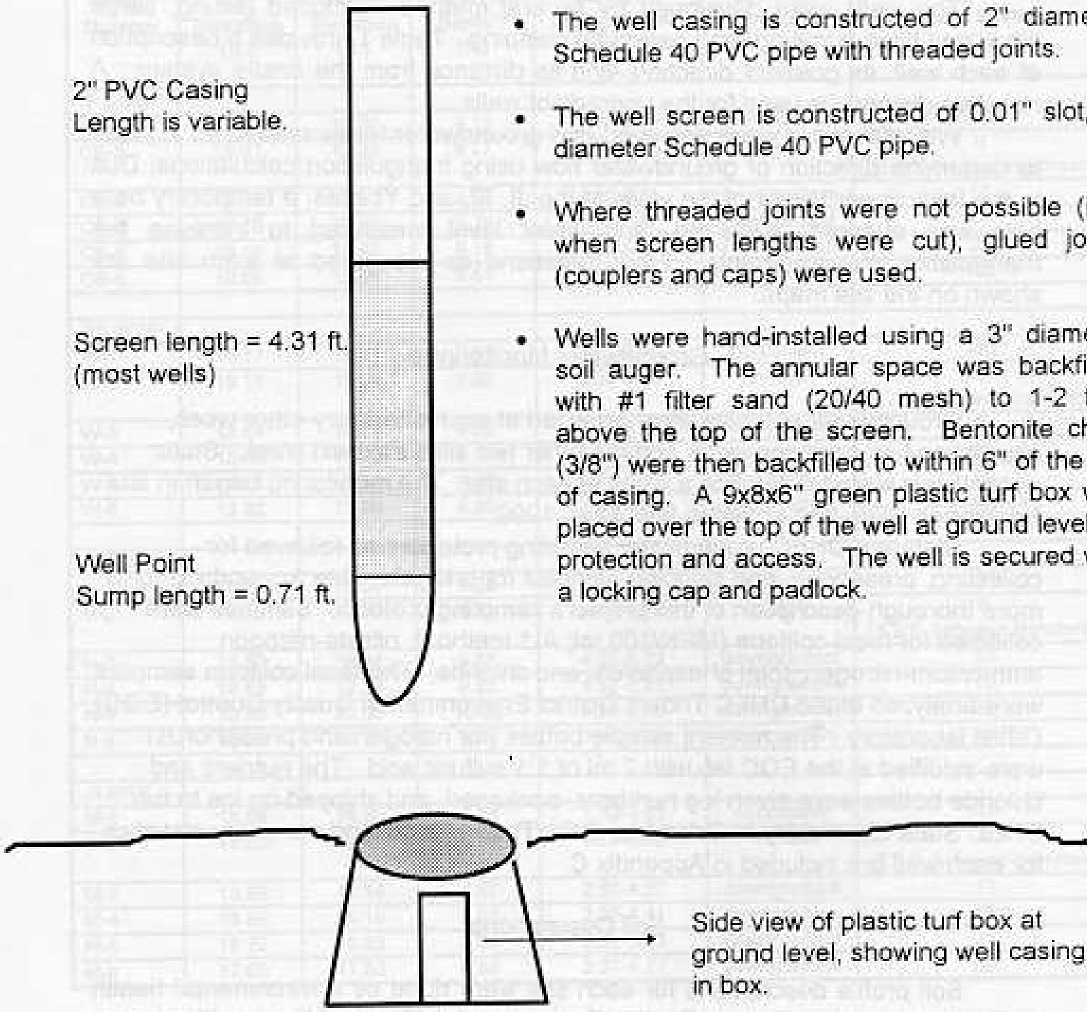
Figure 5. Location of James Island site.

This gave homeowners the ability to mow without interference. The wells were provided with locking caps and padlocks.

The wells were developed by several methods, included bailing, surge block and bilge pumping, and peristaltic pumping. Table 1 provides a description of each well, its gradient direction, and its distance from the onsite system. A negative distance is used for the upgradient wells.

Well elevations were surveyed and groundwater levels measured in order to determine direction of groundwater flow using triangulation calculations. Due to the fairly linear layout of the wells at the JI, IP, and YI sites, a temporary bore hole was augered, surveyed, and water level measured to increase the triangulation measurements. Flow directions as measured at each site are shown on the site maps.

TYPICAL MONITORING WELL CONSTRUCTION DIAGRAM



- The well casing is constructed of 2" diameter Schedule 40 PVC pipe with threaded joints.
- The well screen is constructed of 0.01" slot, 2" diameter Schedule 40 PVC pipe.
- Where threaded joints were not possible (i.e., when screen lengths were cut), glued joints (couplers and caps) were used.
- Wells were hand-installed using a 3" diameter soil auger. The annular space was backfilled with #1 filter sand (20/40 mesh) to 1-2 feet above the top of the screen. Bentonite chips (3/8") were then backfilled to within 6" of the top of casing. A 9x8x6" green plastic turf box was placed over the top of the well at ground level for protection and access. The well is secured with a locking cap and padlock.

Figure 6. Typical monitoring well construction diagram.

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Groundwater Monitoring

Groundwater samples were collected at each site every other week, alternating two sites one week and the other two sites the next week. Static water levels were taken once a week at each site. The monitoring began in late November 1995, and ended in late June, 1996.

Standard DHEC groundwater sampling protocol was followed for collecting, preserving, and shipping samples for analysis. See Appendix B for a more thorough description of this project's sampling protocol. Samples were collected for fecal coliform (MPN/100 ml; A-1 method), nitrate-nitrogen, ammonium-nitrogen, total phosphorus, and chloride. The fecal coliform samples were analyzed at the DHEC Trident District Environmental Quality Control (EQC) Office laboratory. The nutrient sample bottles (for nitrogen and phosphorus) were acidified at the EQC lab with 2 ml of 1:1 sulfuric acid. The nutrient and chloride bottles were given log numbers, packaged, and shipped on ice to the DHEC State Laboratory in Columbia, S.C. The raw data and summary statistics for each well are included in Appendix C.

Soil Descriptions

Soil profile descriptions for each site were done by environmental health professionals at the Trident District Environmental Health Office in Charleston County. Among other duties, this office administers the DHEC septic tank program for Charleston, Dorchester, and Berkeley counties. Since one of the main objectives of this study was to determine the effectiveness of the six-inch separation distance between the seasonal high water table (SHWT) and the trench bottom, we felt it was important to have the SHWT determined by those who run the septic tank program. This could also allow for a comparison of the estimated SHWT using soil color (as done by the health departments) and the SHWT as measured in the wells during this study.

The soil boring logs are included in Appendix D. Soil boring logs were not done on each well during installation because several wells were installed simultaneously and the personnel were not available to describe each bore hole. At the IP site the auger used by the health department staff only went to 48 inches deep, therefore the descriptions are only for the top four feet. At the JI site, the soil profile descriptions are from 1986, when the health department conducted a re-evaluation of the site. We chose not to do additional soil borings because we did not want to disturb the extensive landscaping of this home any more than had already been done by well installation. The borings done at the YI and RA sites extended to the water table, essentially the length of the wells.

Rainfall

Rainfall data was gathered from the S.C. State Climatology Office for the four monitoring stations that were closest to the study sites. The rainfall data is included with the data figures and discussion for each site.

Table 1. Monitoring well descriptions.

Well Number	TOC* Elevation (ft.)	Ground Elevation (ft.)	Total Well Depth** (ft.)	Screened Interval Depth from TOC (ft.)	Gradient Direction	Distance from Septic System (ft.)
IP SITE						
CB-1	19.06	19.26	9.13	4.20-8.51	upgradient	-22
CB-2	19.07	19.38	9.27	4.34-8.65	in-field	0 (5 ft. between trenches)
CB-3	19.37	19.50	9.23	4.30-8.61	downgradient	10
CB-4	19.10	19.38	9.29	4.36-8.67	downgradient	15
CB-5	19.59	19.90	9.18	4.25-8.56	downgradient	25
CB-6	19.66	19.95	9.61	4.68-8.99	side-gradient?	105
RA SITE						
W-1	19.17	19.31	8.60	3.67-7.98	upgradient	-40
W-2	19.11	19.26	7.28	2.35-6.66	in-field	0 (4.3 ft. between trenches)
W-3	18.64	18.73	9.22	4.29-8.60	downgradient	10
W-4	18.59	18.72	9.48	4.55-8.86	downgradient	15
W-5	18.25	18.34	8.87	3.94-8.25	downgradient	25
W-6	13.92	13.99	5.60	2.64-4.98	side-gradient	185 (approx.)
YI SITE						
N-1	18.26	18.56	8.25	3.32-7.63	upgradient	-37
N-2	19.50	19.67	9.81	4.88-9.19	in-field	0 (3.9 ft. between trenches)
N-3	19.80	19.94	9.85	4.92-9.23	downgradient	10
N-4	19.69	19.72	9.85	4.92-9.23	downgradient	15
N-5	19.55	20.06	10.22	5.29-9.60	downgradient	25
N-6	19.68	19.89	8.87	3.94-8.25	side-gradient	26
JI SITE						
M-1	18.69	18.90	3.78	1.30-3.63	upgradient	-20
M-2	19.23	19.40	4.34	1.78-3.72	in-field	0 (3.5 ft. between trenches)
M-3	18.88	19.14	4.67	2.66-4.52	downgradient	10
M-4	18.99	19.15	5.03	2.06-4.41	downgradient	15
M-5	18.72	18.83	5.65	2.82-5.03	downgradient	25
M-6	17.68	17.83	4.89	2.37-4.27	downgradient	107

*TOC = top of well casing
Elevations are relative to a temporary benchmark established at 20 feet above sea level.
**The total well depth is measured from the inside of the well point or cap where the light buzzer touches to the TOC.

RESULTS AND DISCUSSION

Rainfall

According to the Charleston County Soil Survey, the average annual precipitation is 49.1 inches. This is almost totally in the form of rain. For the months of December through June, the average precipitation totals 24.1 inches. Also for those months, one year in ten will have less than 7.4 inches and one year in ten will have more than 39.8 inches of precipitation.

The rainfall recorded at the stations closest to each site for the sampling period of late November to mid June is as follows:

IP site ------	12.53 inches
RA site -----	13.19 inches
YI site ------	16.54 inches
JI site -------	11.16 inches

Isle Of Palms Site

<u>Location</u>

This site is located on Hamlin Creek which feeds into the Atlantic Intracoastal Waterway (ICWW, watershed 03050202-060). The ICWW is a Class SB water. Class SB is defined as tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption; also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.

Hamlin Creek is a diurnal waterbody with a mean tide range of 5.09 feet, a spring tide of 5.90 feet, and a mean tide level of 2.75 feet. Shellfish harvesting in Hamlin Creek is restricted from its confluence with Swinton Creek to the ICWW, which includes this site location.

Water quality data from the shellfish water quality sampling station closest to this site show that 23% of the samples exceeded an MPN of 43/100 ml over 30 sampling events which occurred from February 1994 to April 1996. A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 46 MPN/100 ml and a salinity of 34%. The most likely source may be the treated wastewater discharged from a yacht which is moored at this dock.

The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 7.

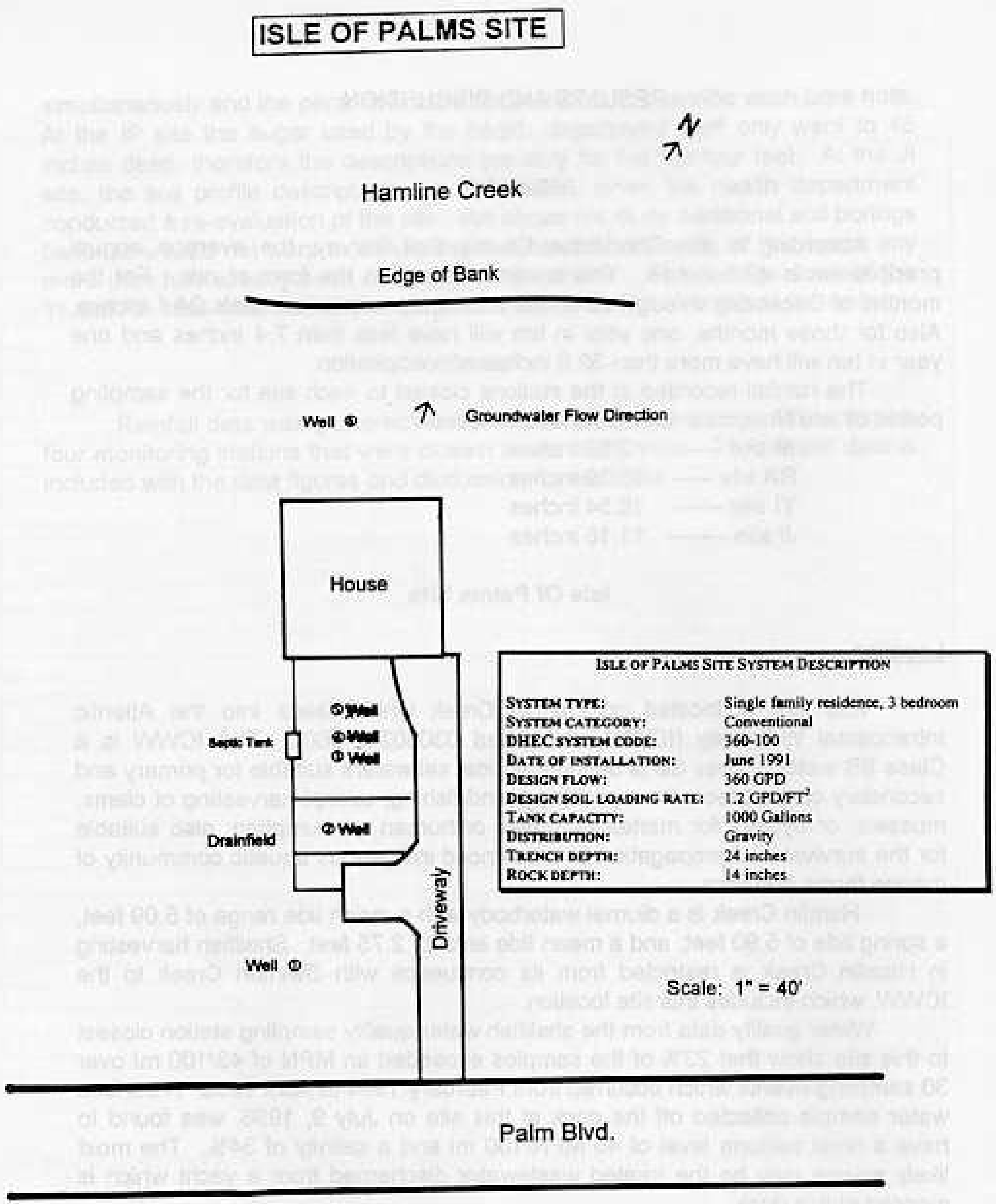


Figure 7. Isle of Palms site map.

Septic System Performance Survey

The performance survey as completed by the residents indicates that no problems have been experienced with this five year old system. With only two adults residing in this home and no garbage disposal, we assume that the loading to this system is well below its design capacity. A discrepancy between the permit and the survey was noted, however. The permit was for a three bedroom home, and the survey response indicated that it is a four bedroom home.

Groundwater Levels

As stated previously, the six groundwater monitoring wells were installed in November, 1995. In most years, the water table would rise throughout the winter to its ‘seasonal high’ until evapotranspiration by plants in the spring and summer would again draw it back down. We fully anticipated the water table to rise above the level at which the wells were installed. However, rainfall levels for the 1995-96 winter season were about 10-12 inches below normal (Fig. 8 and Table 2).

Figure 9 illustrates the relatively steady decline in water table levels throughout the monitoring period with occasional rises following rain events. Well CB-5 in particular never yielded enough water to collect samples. This may have been due, in part, to the well’s close proximity to several large live oak trees. Well CB-6 yielded only one sample. Water levels were taken on a weekly basis and water samples were taken every other week. Therefore, a temporary rise in water levels did not always coincide with a sampling event. Wells CB-5 and CB-6 were the two farthest wells downgradient from the septic system. As a consequence, the extent of the septic tank effluent plume could not be adequately characterized.

With regard to separation distance between the trench bottom and the seasonal high water table, the minimum 6-inch separation required by R.61-56 was never approached. The trench depth at the IP site was the conventional 24-inch depth. Throughout the study period, the water table below the drainfield was never higher than 8.27 feet below the ground surface. Therefore, the minimum separation distance between the trench bottom and the seasonal high water table (as measured by well CB-2) during the study was 6.27 feet. The maximum separation distance was 7.1 feet and the average separation distance was 6.71 feet.

Water Quality

The in-field well (CB-2) and downgradient wells (CB-3, CB-4) had persistently and substantially higher chloride levels than the upgradient well (CB-1), as illustrated in Figure 10. This indicates that the wells were located within the septic tank effluent plume. It may be reasonable to assume that CB-6 was

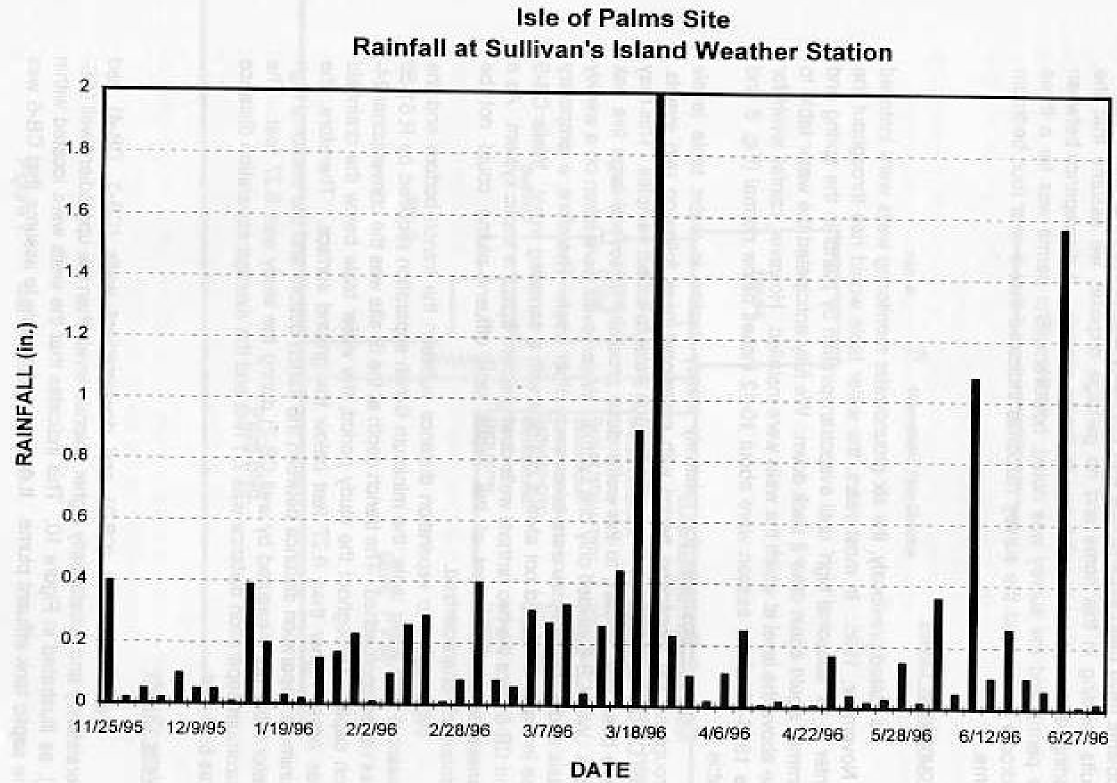


Figure 8. Rainfall at station closest to IP site.

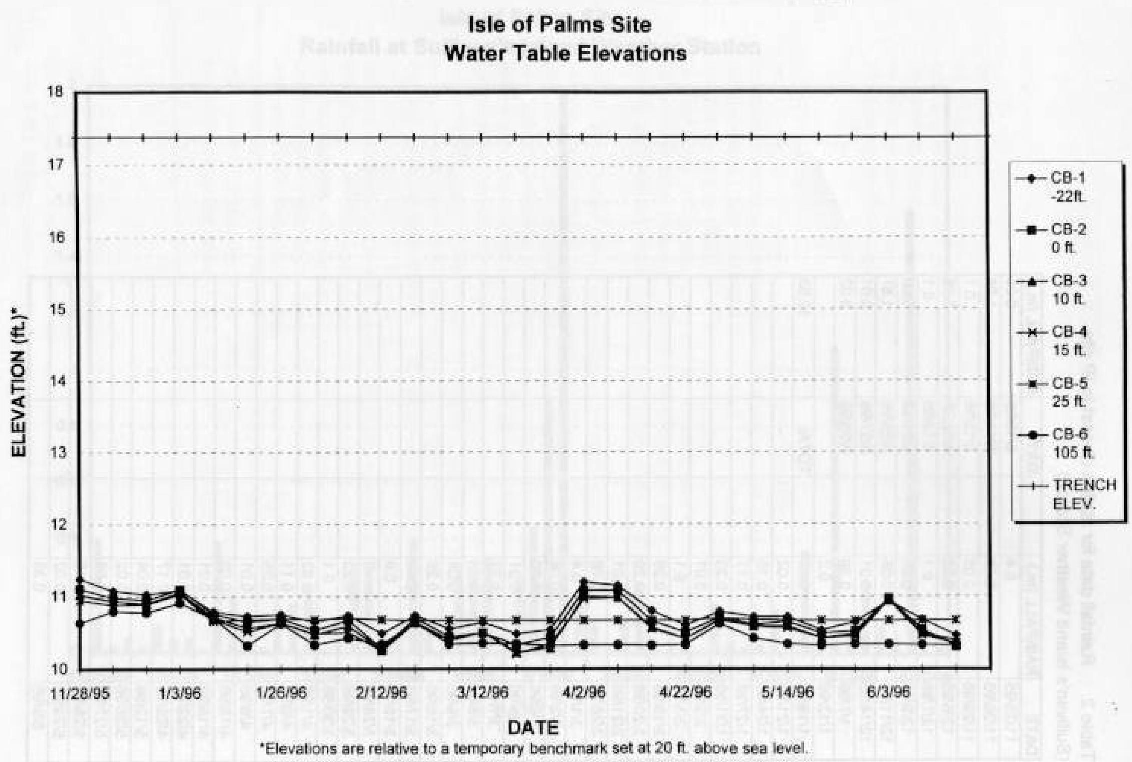


Figure 9. Water table elevations at IP site.

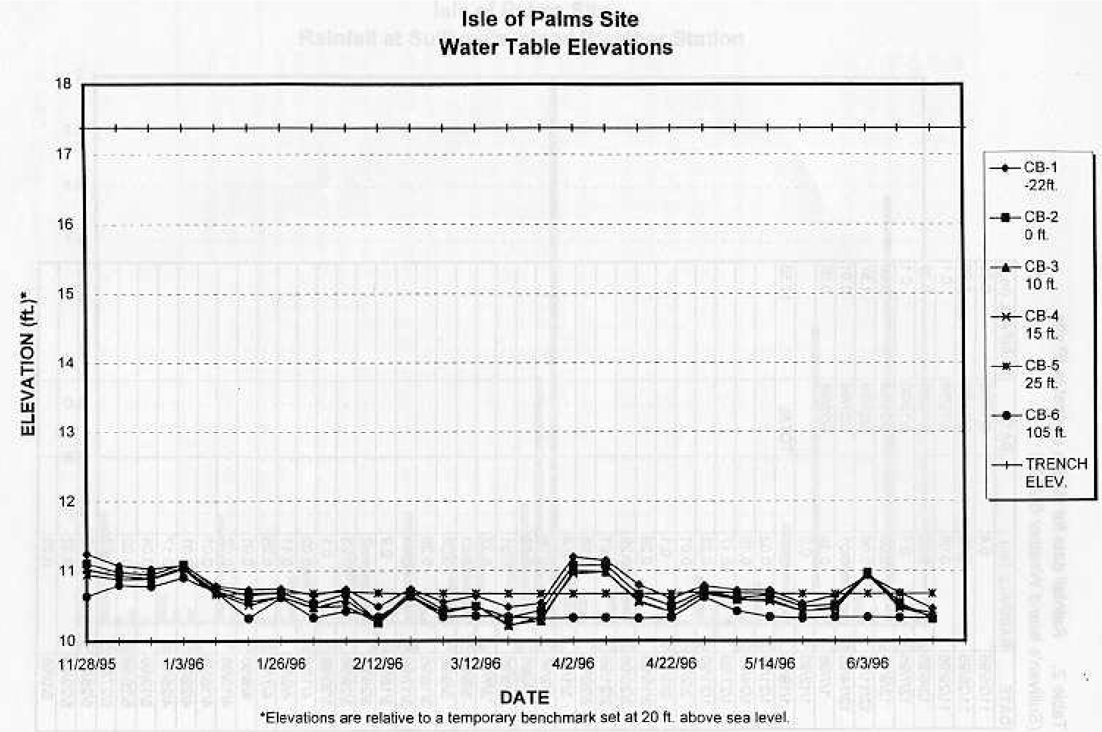


Figure 9. Water table elevations at IP site.

more side-gradient than downgradient. This assumption is based on its location in relation to the groundwater flow direction (see Fig. 7) and its one-time chloride measurement that was below background levels (Fig. 10).

Nitrate was the predominant form of nitrogen found at this site. This is not surprising given the overall aerobic nature of this site with its sandy soils and large vadose zone. Although nitrate levels were quite variable over time they were greatly and consistently above background levels (Fig. 11). This also supports the assertion that wells CB-2, CB-3, and CB-4 were within the effluent plume. These in-field and downgradient wells often exceeded nitrate drinking water standards (10.0 mg/l) reaching as high as 26.0 mg/l at 15 feet from the edge of the drainfield (well CB-4).

Background ammonium levels were below the detection limit except for a few transitory events (Fig. 12). Ammonium levels in the in-field and downgradient wells ranged from <0.05 to 0.14 mg/l, indicating a high degree of nitrification occurring under the drainfield. Figure 13 shows that mean ammonium levels were generally at or below background levels.

Total phosphorus (P) also was found to be consistently and substantially higher in the in-field and downgradient wells than the upgradient well, although a geographic trend downgradient could not be discerned (Fig. 14). In other words, there is no real tangible explanation for why wells CB-3 and CB-4 had higher P levels than well CB-2 (2.45 and 2.49 mg/l versus 1.68 mg/l, respectively).

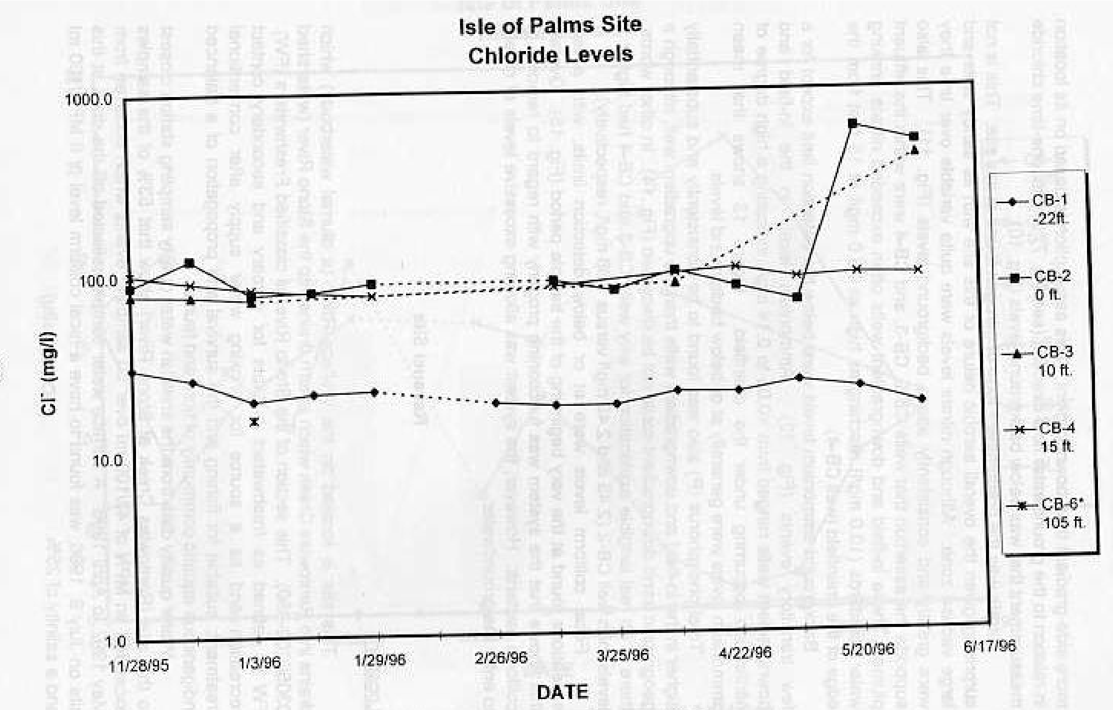
Fecal coliform levels were at or below detection limits, with a few exceptions found at the very beginning of the sample period (Fig. 15). Overall, this shows that the system was functioning properly with regard to removal of coliform bacteria. However, the system was allowing excessive levels of nitrate to enter the groundwater.

Ravenel Site

Location

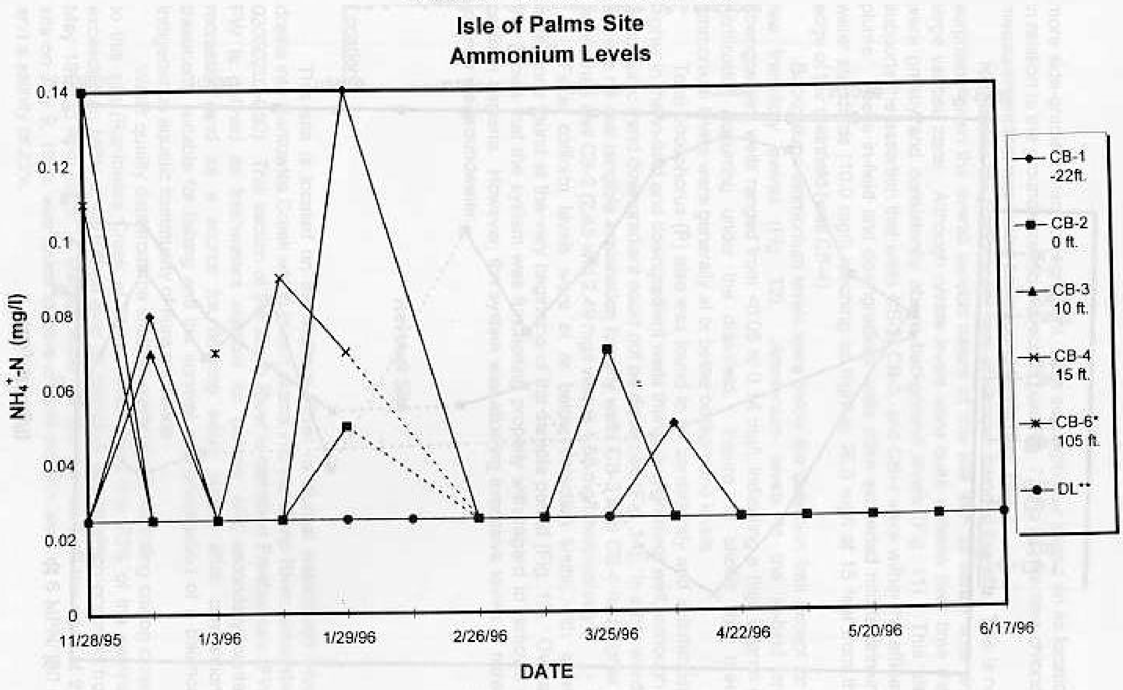
This site is located on the Wallace River (a diurnal waterbody) which drains into Rantowles Creek which in turn drains into the Stono River (watershed 03050202-050). This section of the Stono River is classified Freshwaters (FW). FW is defined as freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment; suitable for fishing and the survival and propagation of a balanced indigeneous aquatic community of flora and fauna.

Water quality data from the shellfish water quality sampling station closest to this site (Rantowles Creek at Stono River) show that 53% of the samples exceeded an MPN of 43/100 ml over 30 sampling events which occurred from May 1992 to April 1996. A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 6 MPN/100 ml and a salinity of 25%.



*CB-6 produced only one sampling event; CB-5 had none

Figure 10. Chloride levels at IP site.

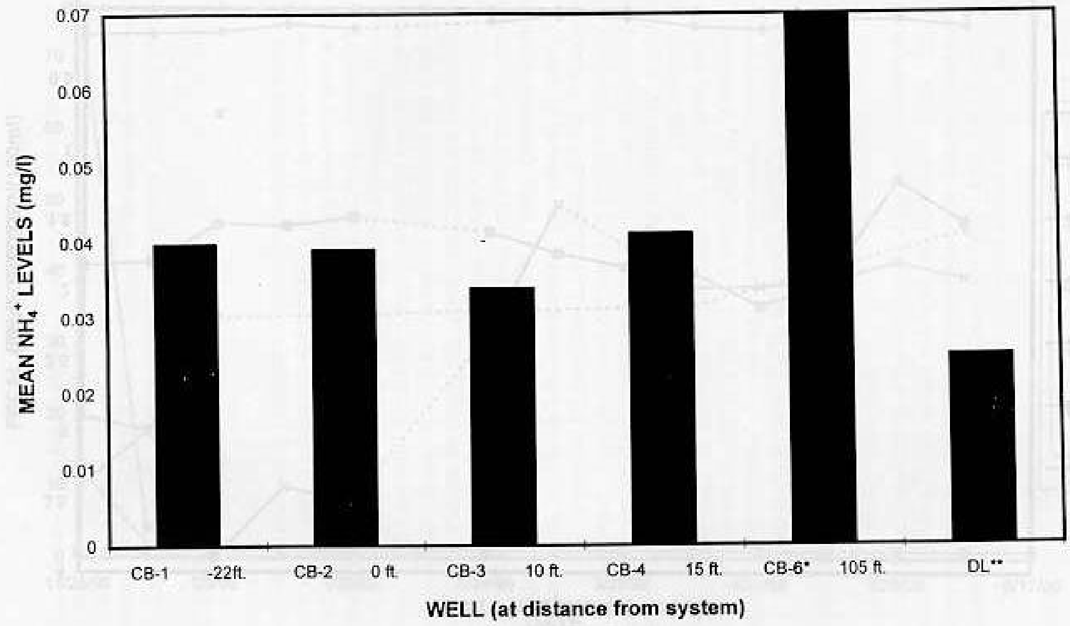


*CB-6 produced only one sampling event; CB-5 had none

**DL = detection limit of 0.025 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

Figure 12. Ammonium levels at IP site.

Isle of Palms Site
Mean Ammonium Levels

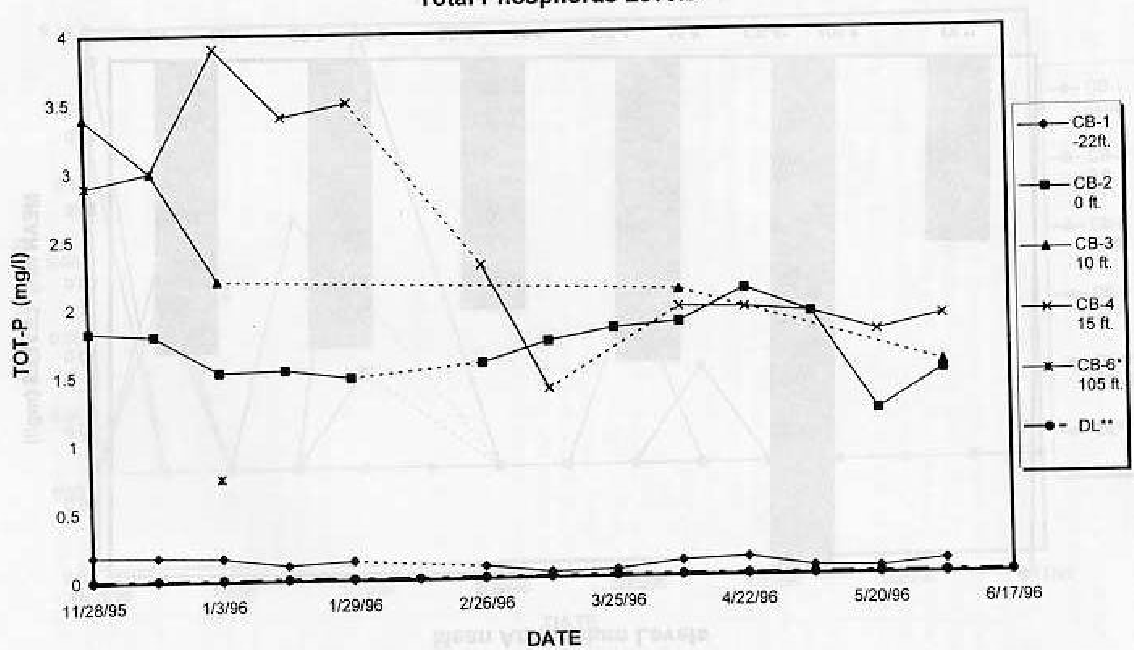


*CB-6 data is from 1 observation

**DL = detection limit of 0.025 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

Figure 13. Mean ammonium levels at IP site.

Isle of Palms Site
Total Phosphorus Levels



*CB-6 produced only one sampling event; CB-5 had none

**DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 14. Total phosphorus levels at IP site.

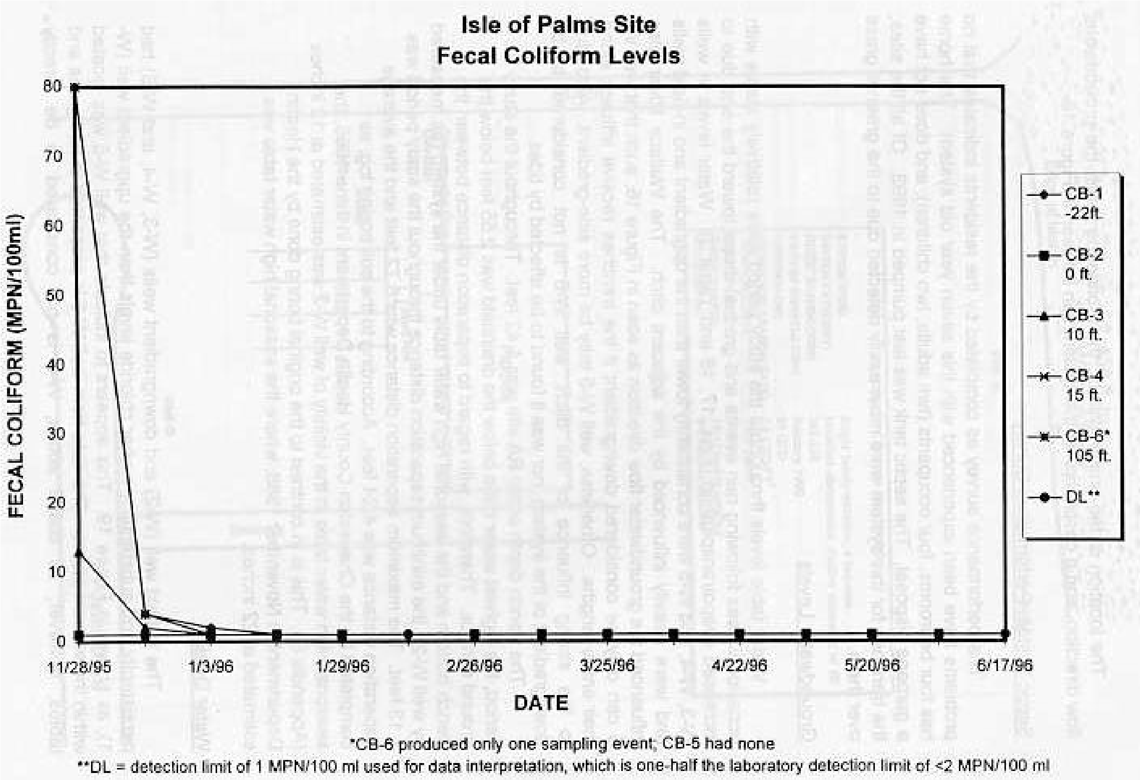


Figure 15. Fecal coliform levels at IP site.

The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 16.

Septic System Performance Survey

The performance survey as completed by the residents indicates that no problems have been experienced with this seven year old system. The home has four bedrooms, four occupants (two adults, two children), and does not have a garbage disposal. The septic tank was last pumped in 1993. Of all the sites, the trenches for this system were most easily detected due to the greener grass over them.

Groundwater Levels

Water table levels throughout the study period were relatively stable with occasional rises following rain events and gradual drops toward the end due to increased evapotranspiration (Figs. 17, 18 and Table 3). Water levels in wells W-3, W-4, and W-5 were consistently lower than the upgradient and in-field wells and were heavily influenced by the adjacent ditch. The Wallace River also influenced the groundwater flow direction as seen in Figure 16, such that well W-5 can only be considered downgradient if the trenches receive effluent along their entire lengths. Otherwise, well W-5 may be more side-gradient. Also, due to the strong influence of

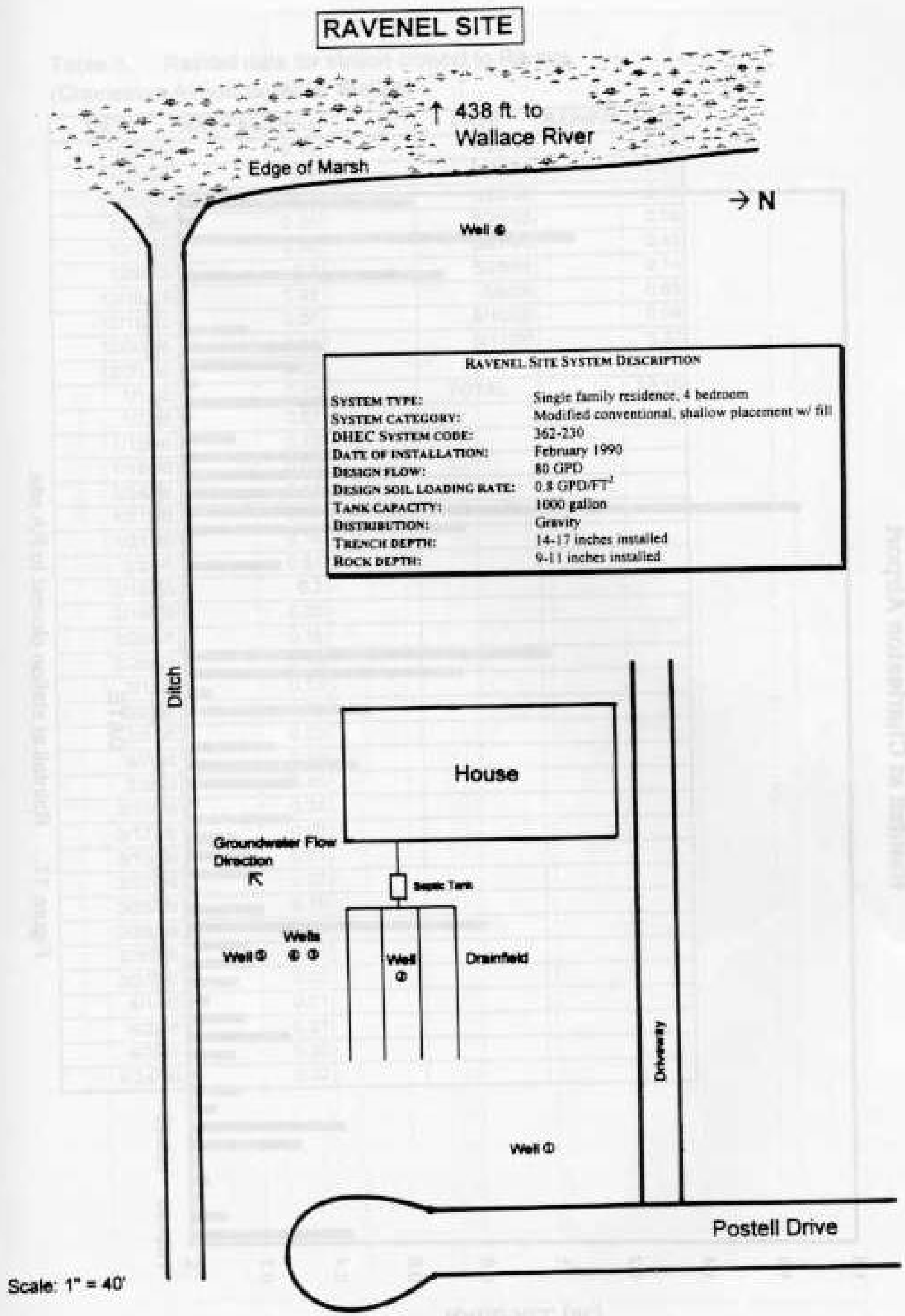


Figure 16. Ravenel site map.

Table 3. Rainfall data for station closest to RA site. (Charleston Airport Weather Station)

DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
11/24/95	0.44	4/26/96	0.76
11/25/95	0.1	4/30/96	1.67
11/29/95	0.02	5/22/96	0.46
12/6/95	0.05	5/26/96	0.58
12/7/95	0.02	5/27/96	0.43
12/9/95	0.3	5/28/96	0.14
12/18/95	0.42	6/9/96	0.65
12/19/95	0.07	6/10/96	0.04
12/30/95	0.14	6/11/96	0.37
12/31/95	0.02		
1/1/96	0.12	**TOTAL**	13.19
1/7/96	0.27		
1/12/96	0.15		
1/19/96	0.05		
1/24/96	0.13		
1/27/96	0.17		
1/31/96	0.16		
2/2/96	0.81		
2/15/96	0.2		
2/16/96	0.02		
2/20/96	0.16		
2/28/96	0.17		
3/1/96	0.13		
3/2/96	0.28		
3/6/96	0.03		
3/7/96	0.29		
3/8/96	0.46		
3/16/96	0.24		
3/17/96	0.02		
3/18/96	0.51		
3/27/96	0.07		
3/28/96	0.75		
3/29/96	0.99		
3/30/96	0.01		
3/31/96	0.02		
4/1/96	0.01		
4/2/96	0.01		
4/7/96	0.26		
4/24/96	0.02		

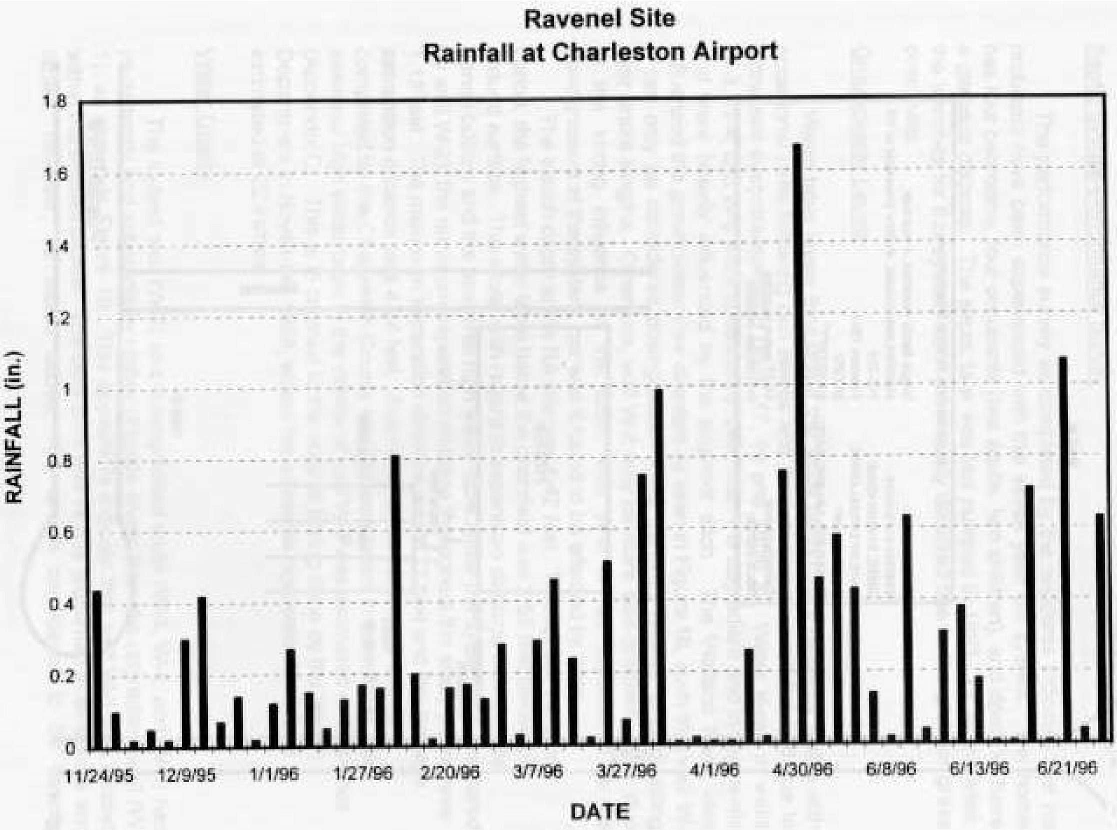


Figure 17. Rainfall at station closest to RA site.

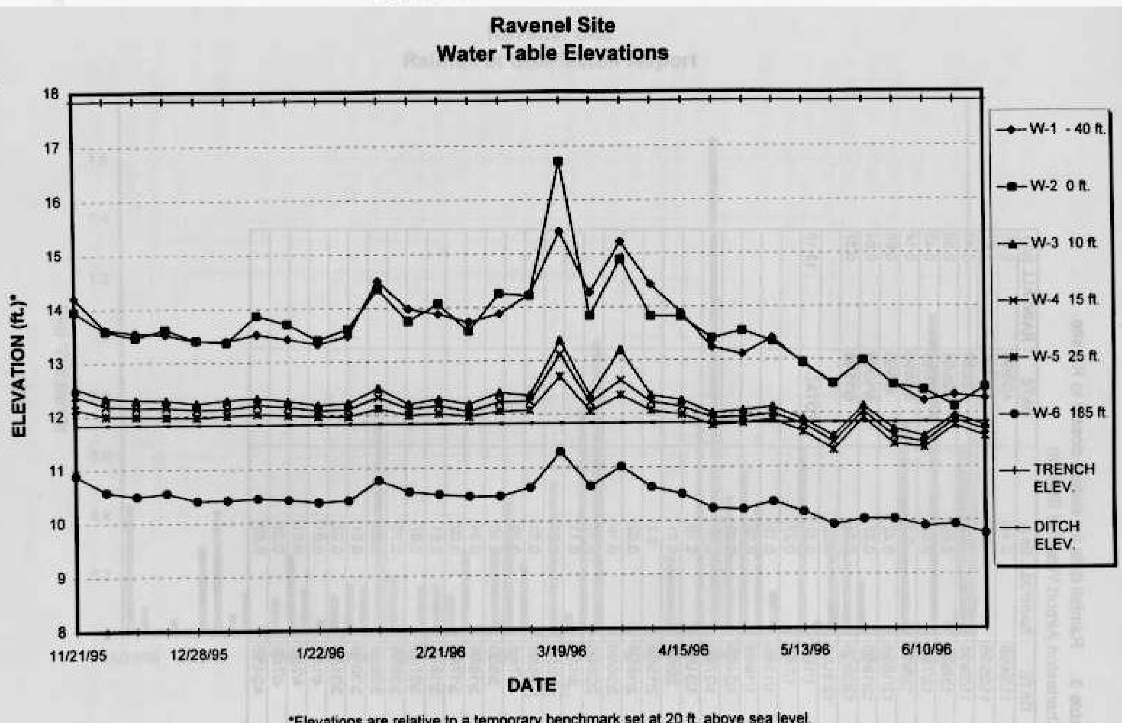


Figure 18. Water table elevations at RA site.

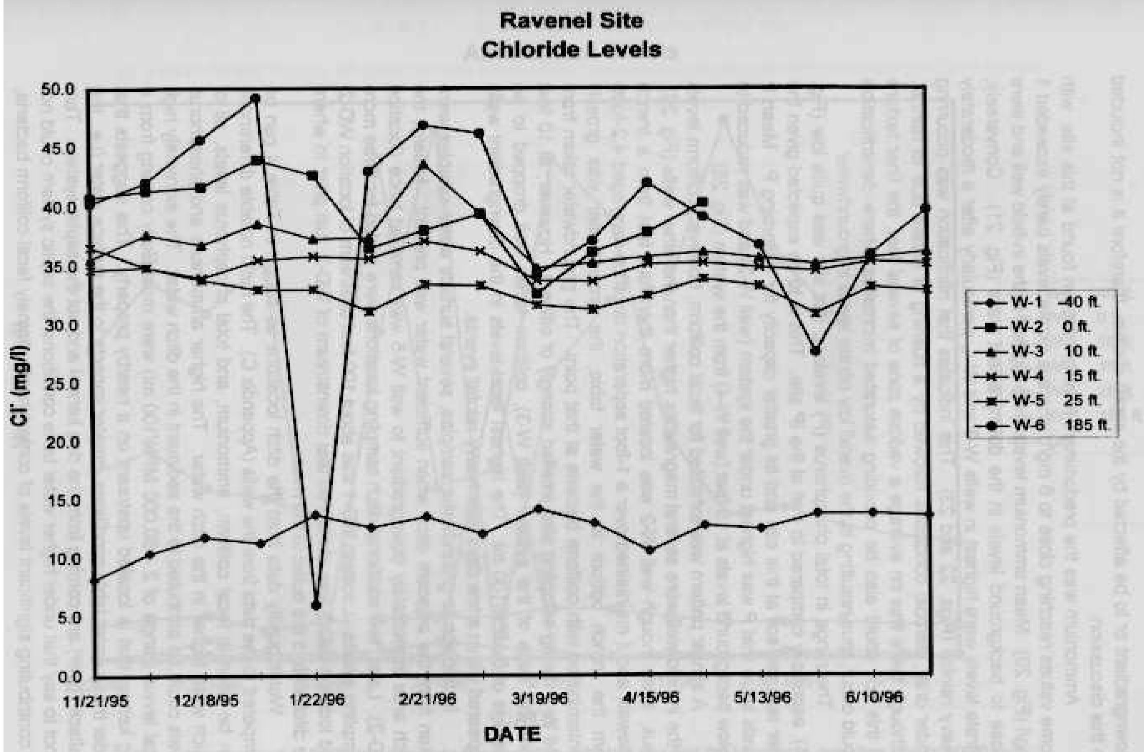
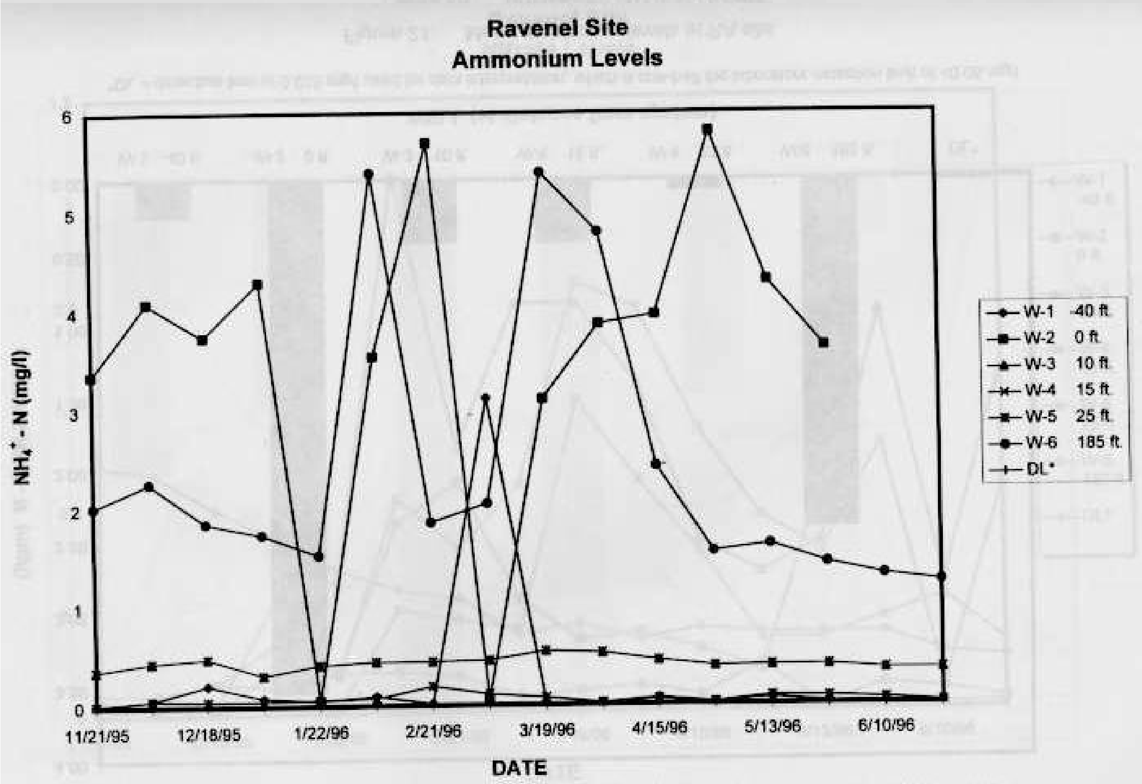


Figure 19. Chloride levels at RA site.



*DL = detection limit of 0.025 used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

Figure 20. Ammonium levels at RA site.

the ditch, well W-6 is not considered to be downgradient of the system, nor was it found to be affected by tides.

The trench depth at the RA site was 1.42 feet. Throughout the study period, the highest water table below the drainfield was 2.55 feet below the ground surface. Therefore, with regard to separation distance between the trench bottom and the seasonal high water table under the system (as measured by well W-2), the minimum separation distance throughout the study period was 1.13 feet. The maximum separation distance was 5.72 feet and the average separation distance was 4.24 feet. According to the soil boring log, as completed by the Charleston County Health Department in June 1996, the seasonal high water table in the vicinity of well W-2 was estimated at 12 inches (Appendix D). This is in contrast to the original boring done by the Health Department in November 1988, where the seasonal high water table was estimated at 22 inches.

Water Quality

The in-field well (W-2) and downgradient wells (W-3, W-4, and W-5) had persistently and substantially higher chloride levels than the upgradient well (W-1), as shown in Figure 19. This appears to indicate that well W-5 was located within the effluent plume. The data from well W-6 is presented in all figures and tables, however, as stated above, W-6 is not considered to be directly downgradient or to be affected by the septic system, therefore it is not included in this discussion.

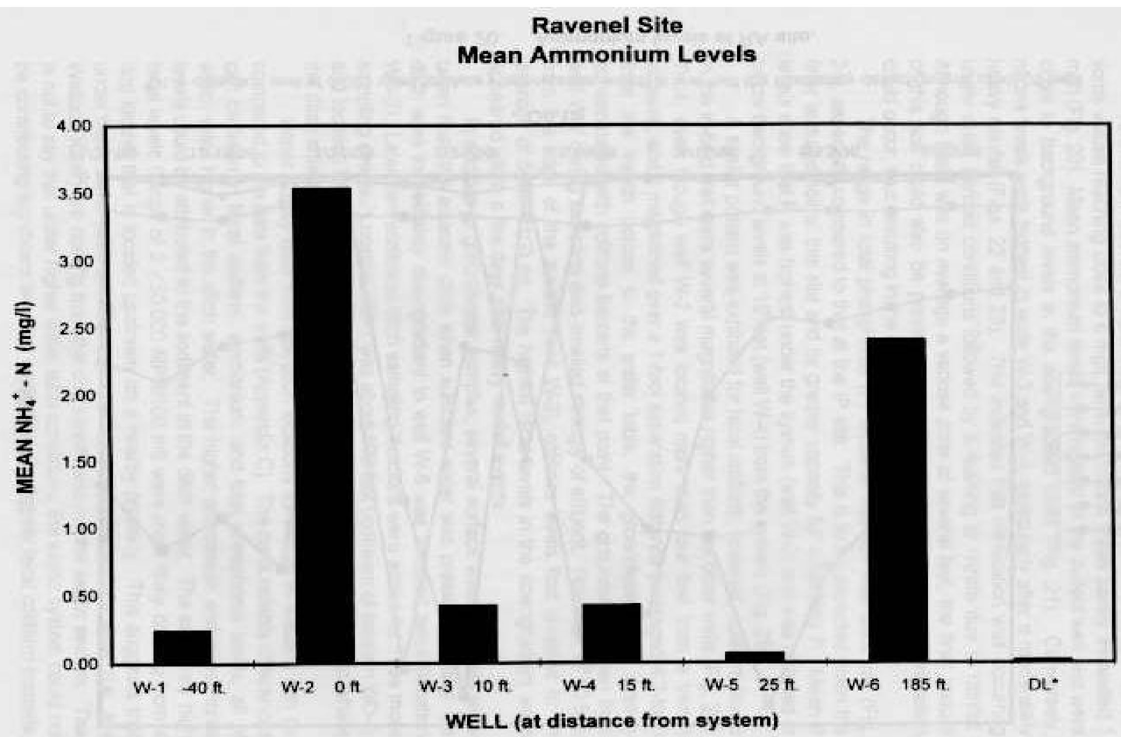
Ammonium was the predominant form of nitrogen found at this site, with some values reaching close to 6 mg/l, whereas nitrate levels barely exceeded 1 mg/l (Fig. 20). Mean ammonium levels were highest in the in-field well and were close to background levels in the downgradient wells (Fig. 21). Conversely, nitrate levels were highest in wells W-3 and W-4, particularly after a moderately heavy rainfall (Figs. 22 and 23). This indicates that nitrification was occurring under drier, aerobic conditions followed by a flushing of nitrate due to rainfall. Although there was on average a vadose zone of several feet, the finer texture of this soil could also be providing saturated microsites where denitrification could occur, thus resulting in the overall low nitrate levels in groundwater.

The range in total phosphorus (P) levels at this site was quite low (Fig. 24), especially compared to that at the IP site. This is to be expected given the finer textured soil at this site and its greater capacity for adsorbing P. Mean P levels show that P was highest under the system (well W-2) and was reduced to below background levels at 15 feet (well W-4) from the system (Fig. 25).

A similar pattern was exhibited for fecal coliform, however, coliform levels in the in-field well were several magnitudes higher than the other wells (Fig. 26). Thus, even though well W-2 was located more than four feet from a trench sidewall, and it maintained over a 1-foot separation distance (averaged 4.2-foot) from the trench bottom to the water table, the groundwater was grossly contaminated with coliform bacteria at that point. The groundwater taken from well W-2 during sampling also smelled strongly of effluent. However, at 10 feet from the edge of the system (well W-3), coliform levels had dropped to an average of 5 MPN/100 ml. The highest fecal levels in the downgradient wells appeared within a few days after heavy rainfall events.

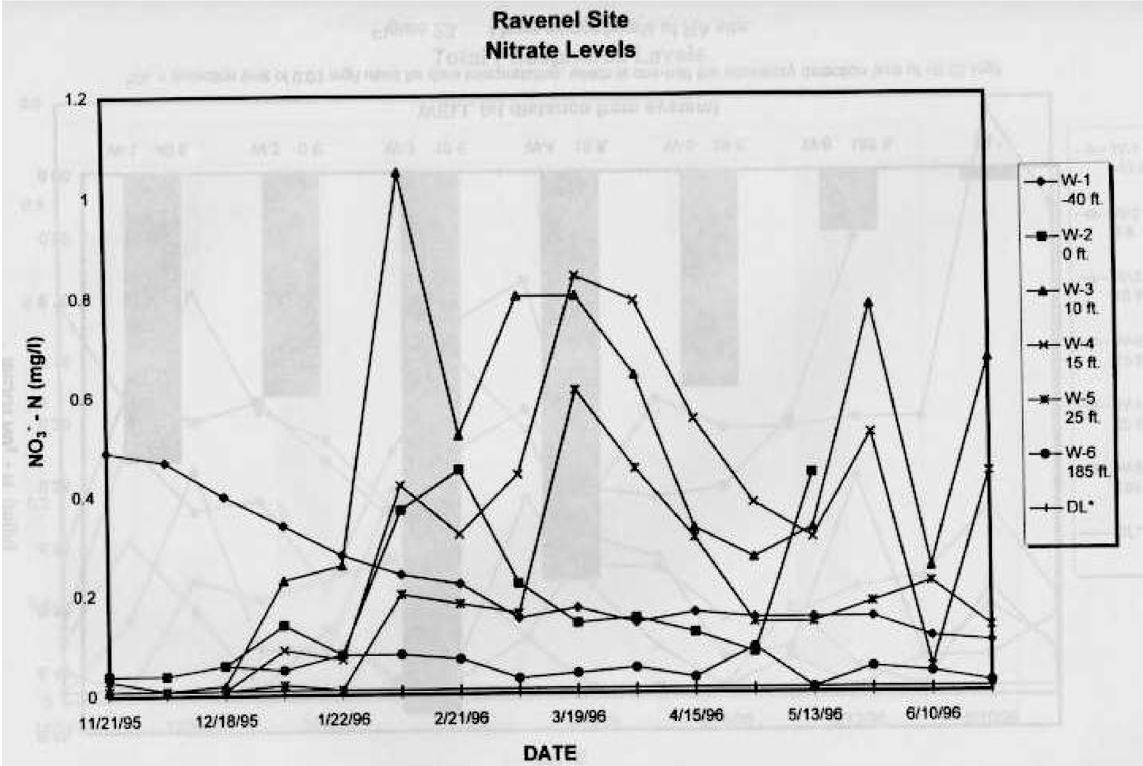
In addition to groundwater samples, several surface water samples were taken from the adjacent ditch when sufficient water was present. Initially, the ditch area immediately downgradient to well W-5 was sampled twice (location WD-2). Later, two additional ditch sampling locations were added for three more sampling events. Location WD-1 was about 100 feet upstream of location WD-2, and location WD-3 was about 180 feet downstream of WD-2, just prior to where the ditch enters the outlet to the river.

Water quality data from the ditch locations as shown in Table 4 can be compared to the data from the wells (Appendix C). The most notable differences can be seen in fecal coliform, ammonium, and total phosphorus levels, all of which were higher in the ditch water. The higher ammonium and phosphorus levels could be attributed to the sediment in the ditch water. The extremely high fecal levels (range of 2 - 50,000 MPN/100 ml) were most likely coming from a dog kennel that is located upstream on a nearby property. This suggests that under these water table conditions, greater impacts to the surface water (i.e., the Wallace River) are coming from the dog kennel and not the septic system. This is not to say that under higher water table conditions, the septic system could not be contributing significant levels of contaminants, namely fecal coliform bacteria, to the surface water as well. This theory would have to be tested when water levels are much higher than they were during this study.



*DL = detection limit of 0.025 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

Figure 21. Mean ammonium levels at RA site.



*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 22. Nitrate levels at RA site.

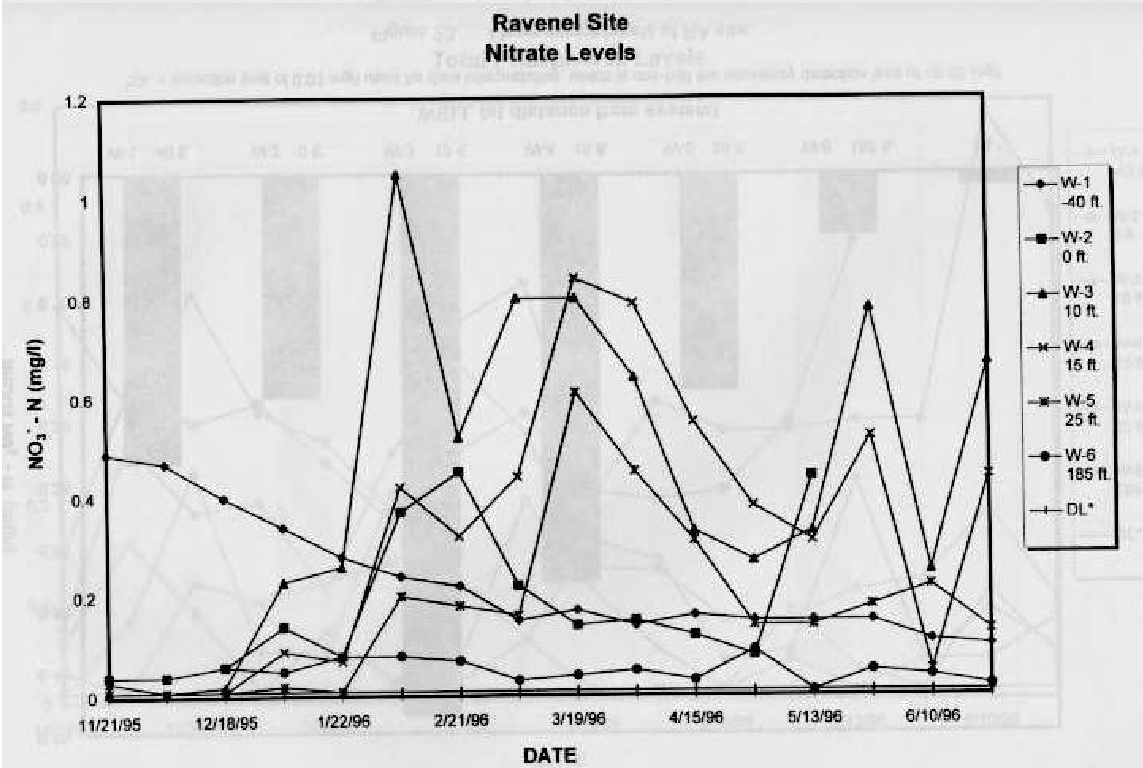
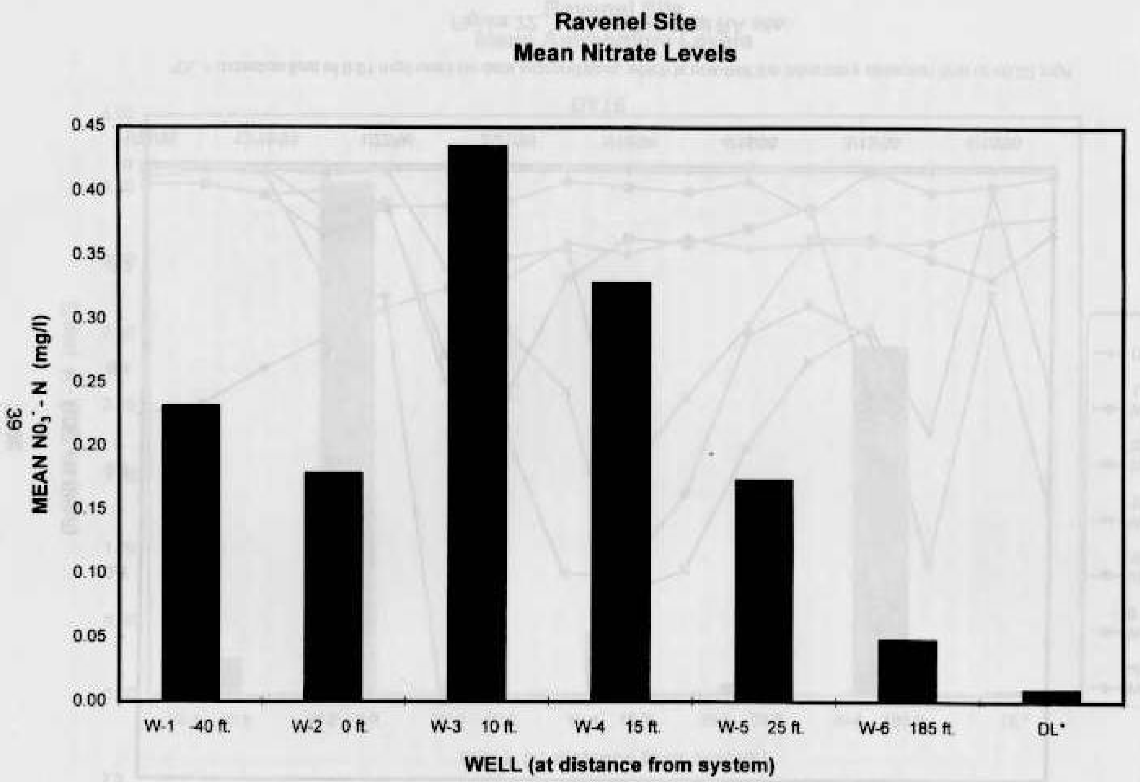
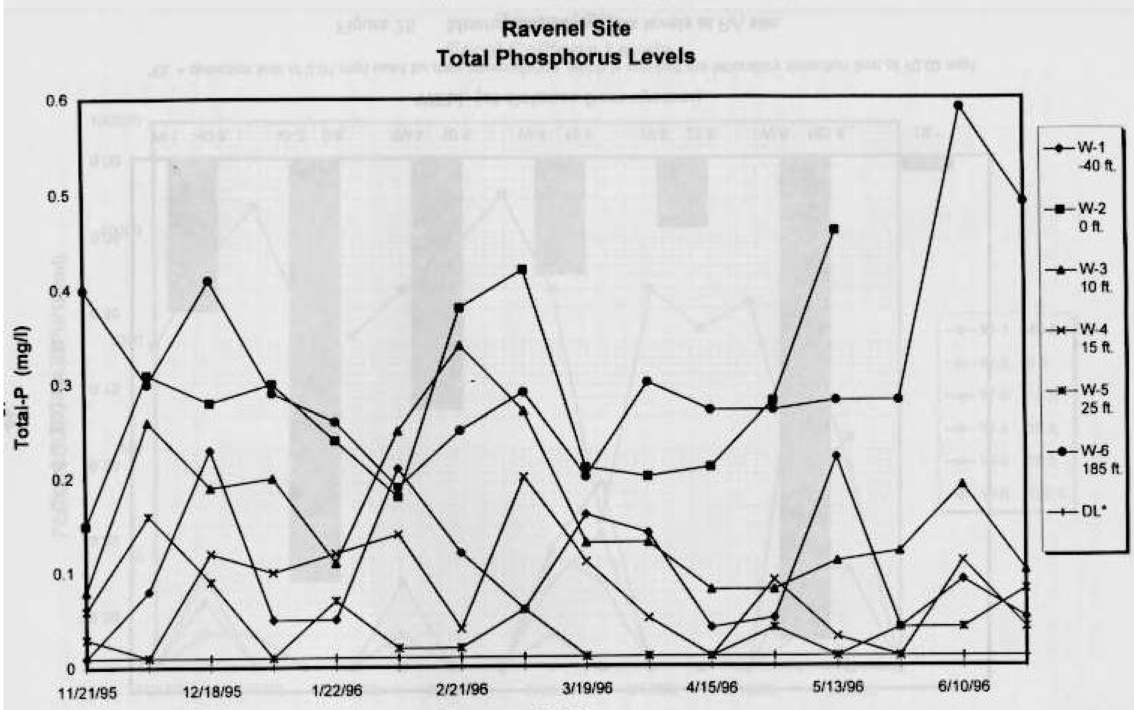

*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 22. Nitrate levels at RA site.



*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 23. Mean nitrate levels at RA site.



*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 24. Total phosphorus levels at RA site.

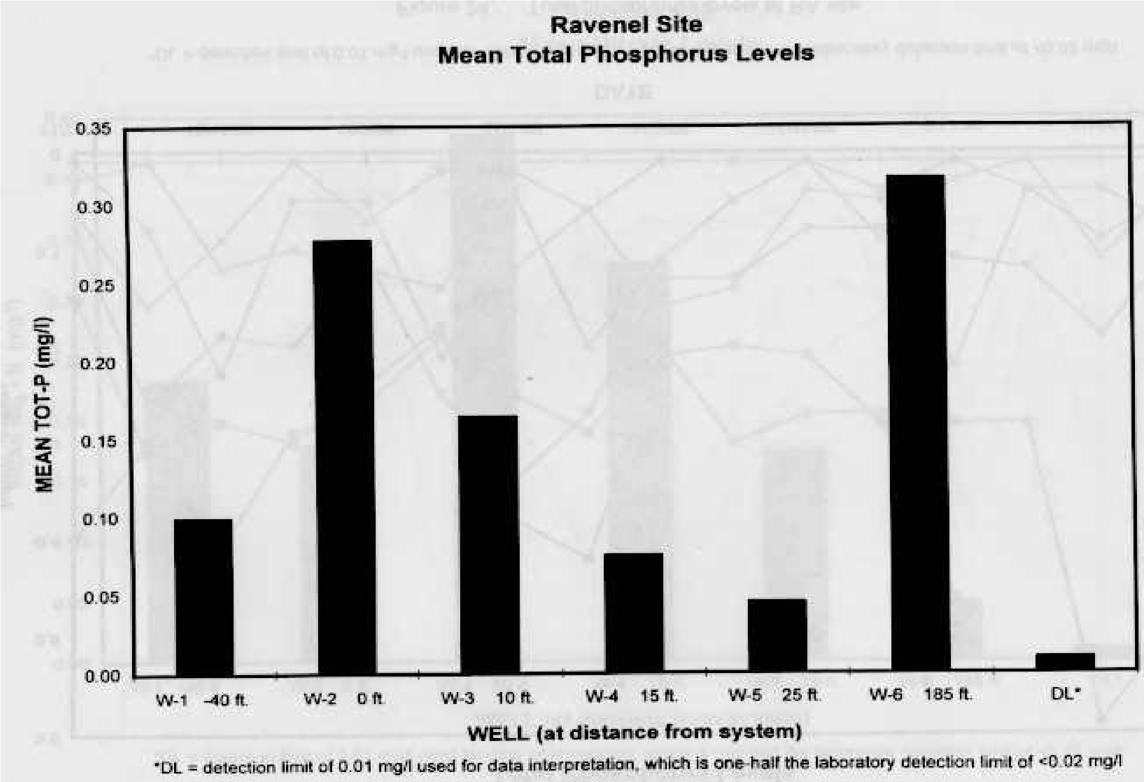


Figure 25. Mean total phosphorus levels at RA site.

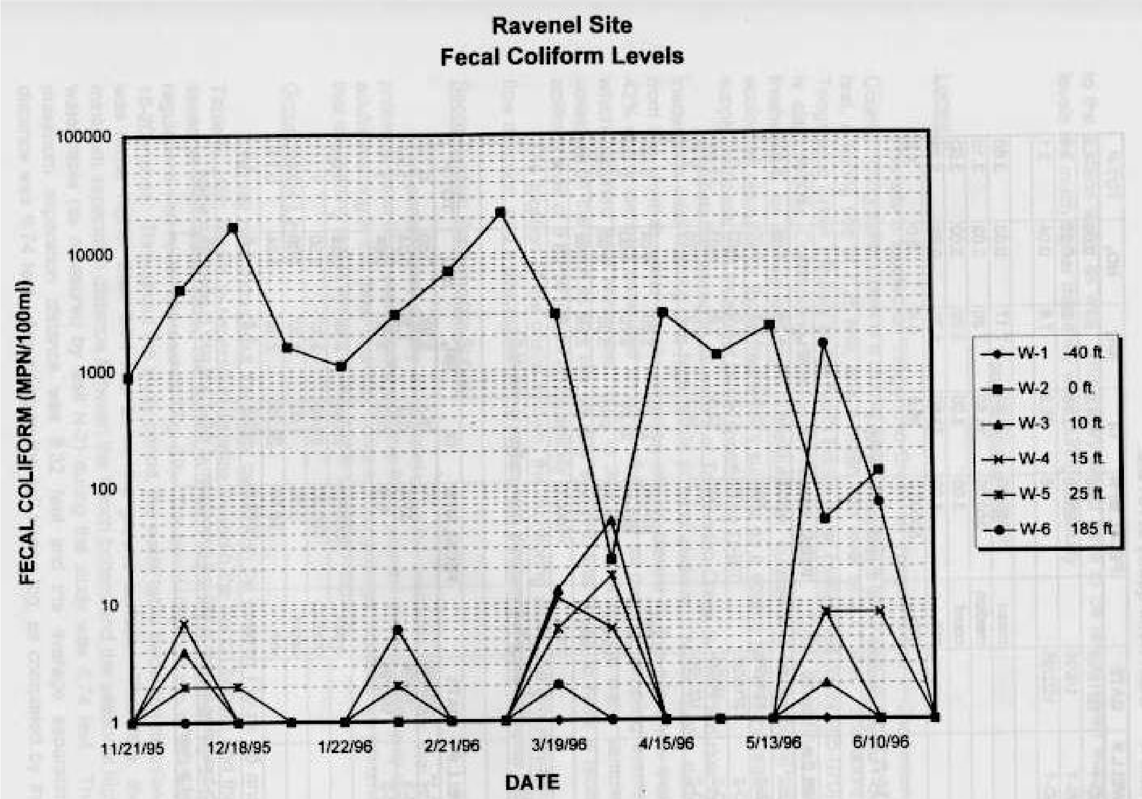


Figure 26. Fecal coliform levels at RA site.

Table 4. Ditch water quality at RA site.

WELL #	DATE		FECAL MPN	Cl	NH_4	NO_3	TOT-P
WD-1*	12/18/95		350	24.6	5.7	0.03	4.9
WD-1	1/9/96		50000	23.6	8.0	0.02	2.8
WD-1	1/22/96		8	26.6	7.8	0.04	3.1
		mean	16786.00	24.93	7.17	0.03	3.60
		median	350.00	24.60	7.80	0.03	3.10
		count	3.00	3.00	3.00	3.00	3.00
		min	8.00	23.60	5.70	0.02	2.80
		max	50000.0	26.6	8.0	0.0	4.9
*WD-1 sampling location is 100 ft. upstream from WD-2							
WELL #	DATE		FECAL MPN	Cl	NH_4	NO_3	TOT-P
WD-2*	11/21/95		1600	16.8	2.26	0.06	0.80
WD-2	12/6/95		500	22.6	5.7	0.02	4.1
WD-2	12/18/95		70	21.9	5.0	0.03	3.5
WD-2	1/9/96		500	23.5	7.8	0.03	1.99
WD-2	1/22/96		2	26.2	7.2	0.05	2.1
		mean	534.40	22.20	5.59	0.04	2.50
		median	500.00	22.60	5.70	0.03	2.10
		count	5.00	5.00	5.00	5.00	5.00
		min	2.00	16.80	2.26	0.02	0.80
		max	1600.0	26.2	7.8	0.1	4.1
*WD-2 sampling location is immediately downgradient to well W-5							
WELL #	DATE		FECAL MPN	Cl	NH_4	NO_3	TOT-P
WD-3*	12/18/95		70	26.4	2.99	0.50	0.73
WD-3	1/9/96		3000	25.2	7.3	0.24	1.39
WD-3	1/22/96		130	28.8	3.92	0.84	1.11
		mean	1066.67	26.80	4.74	0.53	1.08
		median	130.00	26.40	3.92	0.50	1.11
		count	3.00	3.00	3.00	3.00	3.00
		min	70.00	25.20	2.99	0.24	0.73
		max	3000.0	28.8	7.3	0.8	1.4
*WD-3 sampling location is 180 feet downstream of WD-2, just prior to where ditch enters outlet to river							

Yonges Island Site

Location

This site is located on Toogoodoo Creek on Yonges Island in Charleston County. Toogoodoo Creek is a diurnal waterbody with a mean tide range of 6.42 feet, a spring tide of 7.25 feet, and a mean tide level of 3.41 feet. The entire Toogoodoo Creek tributary to the North Edisto River (watershed 03050205-070) is classified as Outstanding Resource Waters (ORW). ORW is defined as freshwaters or saltwaters which constitute an outstanding recreational or ecological resource or those freshwaters suitable as a source for drinking water supply purposes with treatment levels specified by DHEC.

Shellfish harvesting in all waters of Toogoodoo Creek is restricted due to inadequate tidal flushing and high levels of fecal coliform. Water quality data from the shellfish water quality sampling station closest to this site show that 42% of the samples exceeded an MPN of 43/100 ml over 19 sampling events which occurred from November 1992, to July 1995. A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 8 MPN/100 ml and a salinity of 24%.

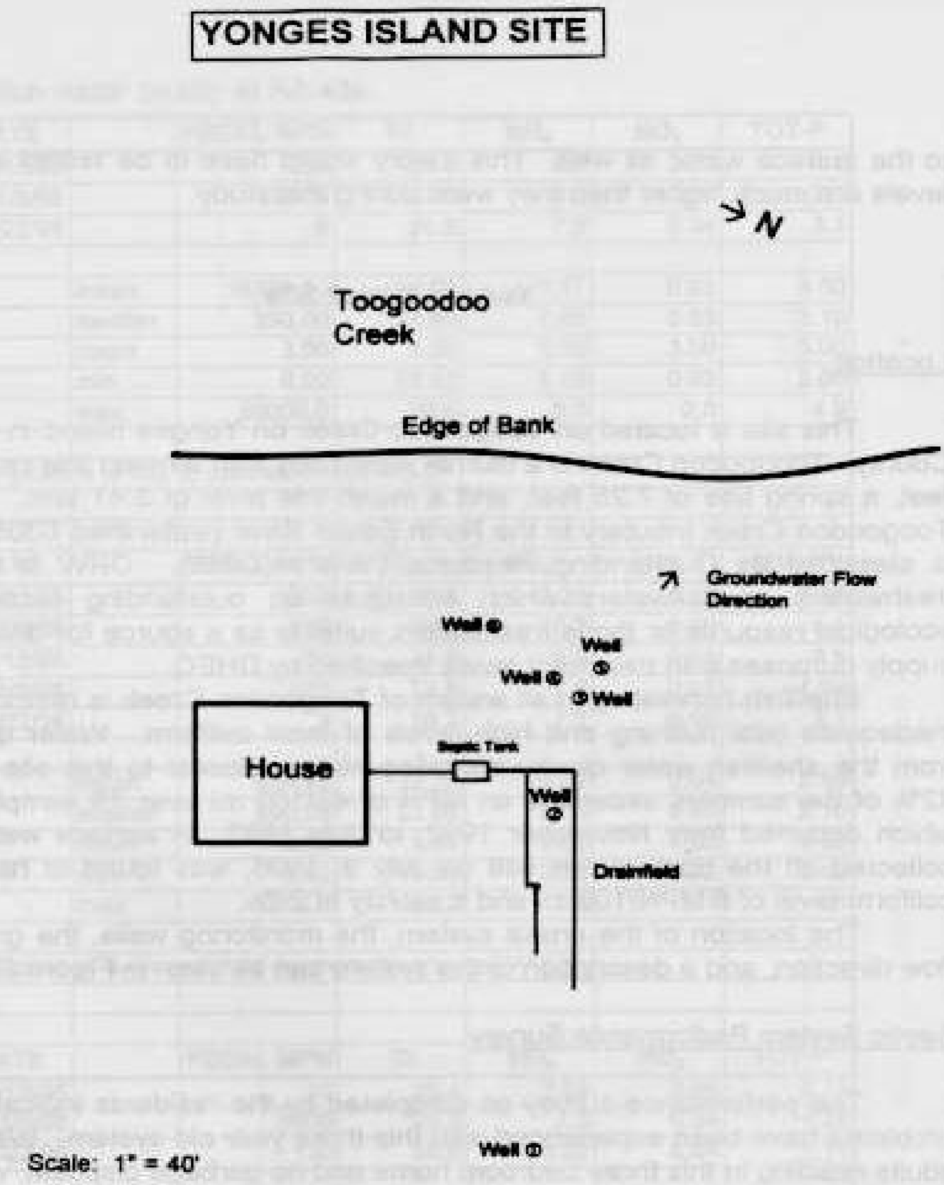
The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 27.

Septic System Performance Survey

The performance survey as completed by the residents indicates that no problems have been experienced with this three year old system. With only two adults residing in this three bedroom home and no garbage disposal, we assume that the loading to this system is well below its design capacity.

Groundwater Levels

Rainfall data throughout the study period can be seen in Figure 28 and Table 5. With regard to separation distance between the trench bottom and the seasonal high water table, the minimum 6-inch separation required by S.C. regulations was never approached (Fig. 29). The trench depth at the YI site was 18-20 inches. Throughout the study period, the water table below the drainfield was never higher than 6.34 feet below the ground surface. Therefore, the minimum separation distance between the trench bottom and the seasonal high water table (as measured by well N-2) during the study was 4.74 feet. The maximum separation distance was 8.32 feet and the average separation distance was 6.74 feet. According to the soil boring log, as completed by the Charleston County Health Department in 1996, the seasonal high water table in the vicinity of well N-2 could potentially be as high as 36 inches (Appendix D).



YONGES ISLAND SITE SYSTEM DESCRIPTION	
SYSTEM TYPE:	Single family residence, 3 bedroom
SYSTEM CATEGORY:	Modified conventional, shallow placement
DHEC SYSTEM CODE:	362-210
DATE OF INSTALLATION:	November 1993
DESIGN FLOW:	360 GPD
DESIGN SOIL LOADING RATE:	0.9 GPD/FT^2
TANK CAPACITY:	1000 gallon
DISTRIBUTION:	Gravity
TRENCH DEPTH:	18-20 inches installed
ROCK DEPTH:	9 + inches

Figure 27. Yonges Island site map.

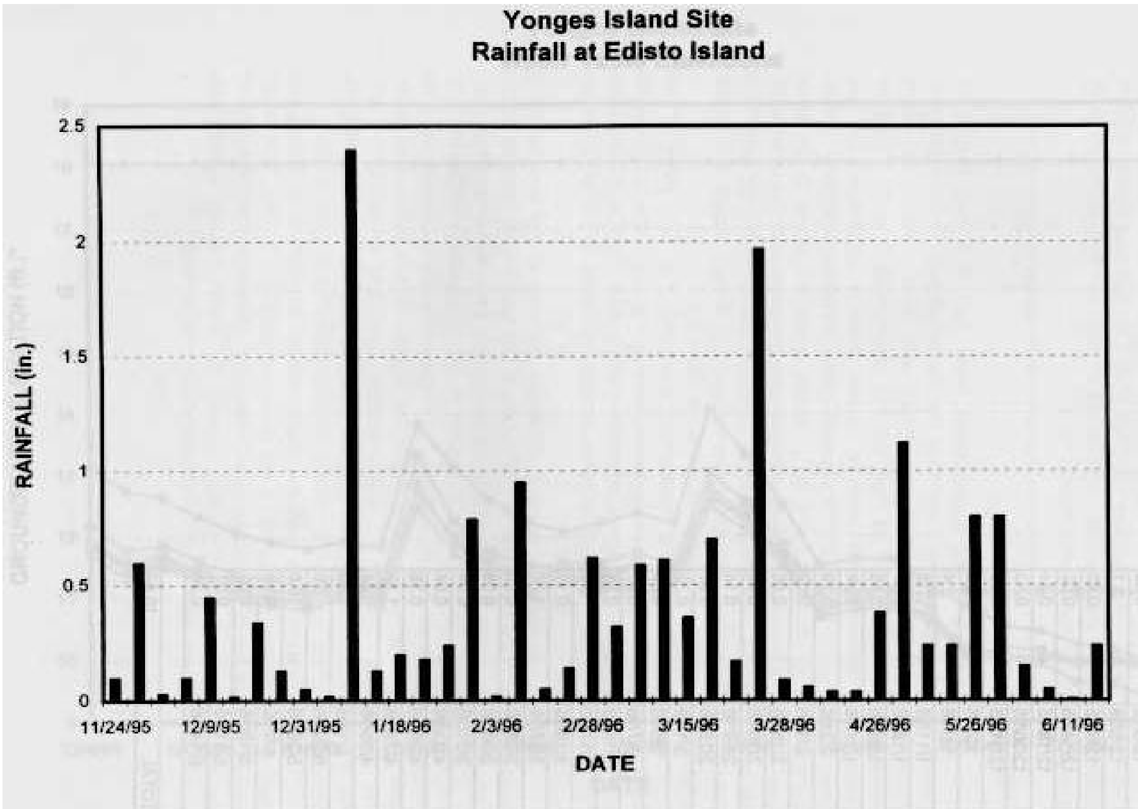


Figure 28. Rainfall at station closest to YI site.

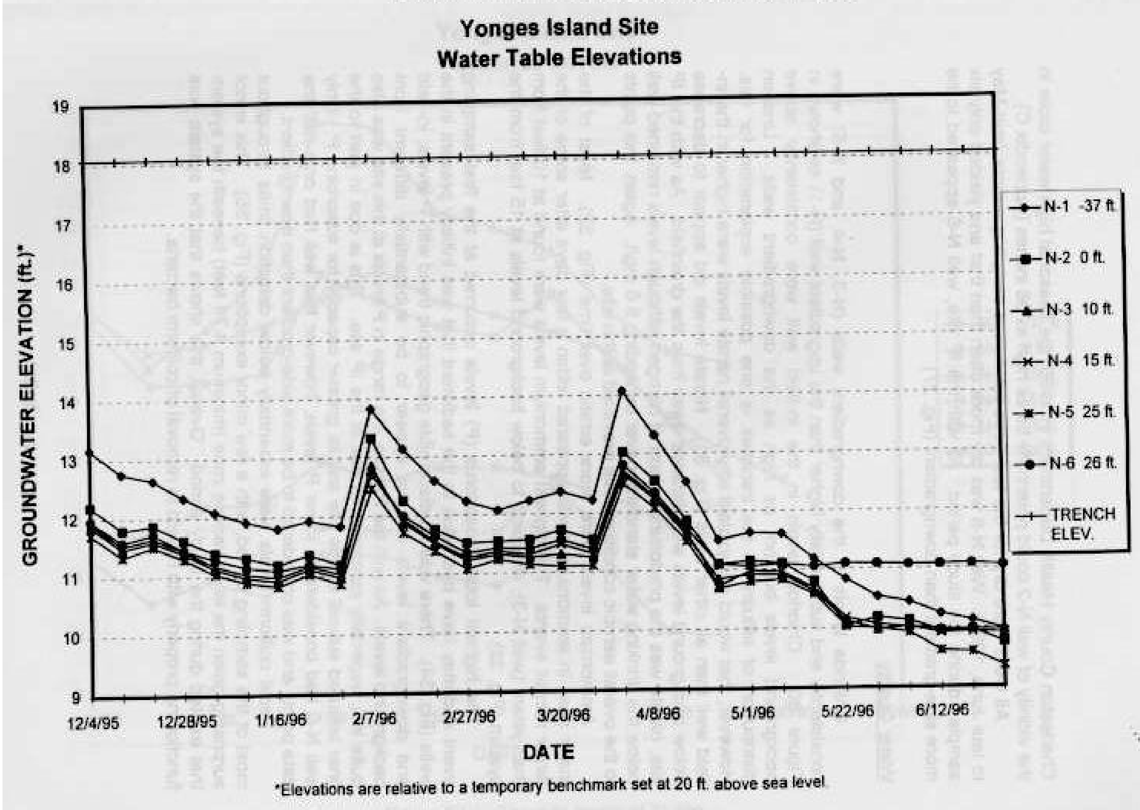


Figure 29. Water table elevations at YI site.

Table 5. Rainfall data for station closest to YI site. (Edisto Island Weather Station)

DATE	RAINFALL (in.)
11/24/95	0.1
11/28/95	0.6
12/5/95	0.03
12/6/95	0.1
12/9/95	0.45
12/14/95	0.02
12/18/95	0.34
12/30/95	0.13
12/31/95	0.05
1/2/96	0.02
1/6/96	2.4
1/11/96	0.13
1/18/96	0.2
1/26/96	0.18
1/31/96	0.24
2/2/96	0.79
2/3/96	0.02
2/15/96	0.95
2/16/96	0.05
2/19/96	0.14
2/28/96	0.62
3/1/96	0.32
3/6/96	0.59
3/7/96	0.61
3/15/96	0.36
3/17/96	0.7
3/18/96	0.17
3/27/96	1.97
3/28/96	0.09
3/30/96	0.06
3/31/96	0.04
4/23/96	0.04
4/26/96	0.38
4/29/96	1.12
4/30/96	0.24
5/1/96	0.24
5/26/96	0.8
5/28/96	0.8
6/9/96	0.15
6/10/96	0.05
6/11/96	0.01
6/14/96	0.24
TOTAL	16.54

All wells were dry for the last three attempted sampling events (mid-May to late June, 1996). Well N-6 was dry more often than that and yielded only six samples during the study period. As with the IP site, well N-6 appeared to be more side-gradient than downgradient (Fig. 27).

Water Quality

Chloride levels in the downgradient wells (N-3, N-4, and N-5) were consistently and substantially higher than the upgradient well (N-1) as shown in Figure 30. Chloride levels in the in-field well were consistently above background levels but not as high as the downgradient wells. Uneven distribution of effluent in the trenches is one possible explanation for this. However, that would not explain why overall nitrate levels were higher in the in-field well than all other wells (Fig. 31). Nitrate levels did appear to decrease below background levels with distance away from the drainfield. As with the IP site, nitrate was the predominant form of nitrogen although levels remained well below the drinking water standard, never exceeding 5.0 mg/l. Again, this points to the overall aerobic conditions that prevailed at this site.

Ammonium levels were more erratic over time (Fig. 32). Most of the major rises in ammonium levels appeared within a few days after some of the larger rainfall events. The highest ammonium levels were found at 10 feet from the system (well N-3), dropping to below background levels at 15 feet from the system (Fig. 33).

The highest total phosphorus (P) levels occurred at the first sampling event and may have been due to the sediment that was initially present in the wells (Fig. 34). There was no discernible geographic trend with P levels; in-field and downgradient levels did not appear to be substantially different from background levels. As with the RA site, the range in P levels at this site was also quite low, especially compared to that at the IP site. This is due in part to the finer textured subsoil at this site and its greater capacity for adsorbing P. Only well N-6 had considerably lower P levels, however this well had only half the data points and was considered to be more side-gradient than downgradient.

Fecal coliform levels were essentially below detection limits throughout most of the sampling period, with a few minor exceptions (Fig. 35). This is not surprising given the large vadose zone (minimum 4.74 feet) beneath the system that existed during the study period. Overall, this shows that the system was functioning properly with regard to removal of coliform bacteria.